The Knee 21 (2014) 514–517

Contents lists available at ScienceDirect

The Knee

Knee valgus angle during single leg squat and landing in patellofemoral pain patients and controls

Lee Herrington *

Allerton Building, University of Salford, Manchester M6 6PU, United Kingdom

ARTICLE INFO

Article history:
Received 25 March 2013
Received in revised form 23 October 2013
Accepted 13 November 2013

Keywords:
Limb load
Alignment
Pain

ABSTRACT

Background: Patellofemoral pain (PFP) is a commonly presenting disorder of the lower limb, frequently effecting young physically active individuals particularly females. The condition has been associated with poor control of limb alignment while undertaking unilateral limb loading tasks. This poor alignment of the limb is believed to alter loading stress within the patellofemoral joint. This study aims to investigate the degree of knee valgus, assessed as 2D frontal plane projection angle (FPPA) during single leg squatting (SLS) and hop landing (SLL) tasks in patients with PFP and compare their performance to controls and the uninjured limb.
Method: Twelve female subjects with unilateral PFP formed the patient group and thirty asymptomatic females formed the control group. They had their 2D frontal plane projection angle (FPPA) assessed during single leg squatting (SLS) and hop landing (SLL) tasks.
Results: In the asymptomatic control group the mean FPPA for SLS was 8.4±5.1° and SLL had a mean FPPA of 13.5±5.7°. In the PFP group the mean FPPA for SLS was 16.8±5.4° and SLL had a mean FPPA of 21.7+/−3.6°, these differences were significant ($p < 0.01$) for both tasks.
Conclusion: Patients with PFP have a greater degree of knee valgus on unilateral limb loading task than either their contralateral asymptomatic limb or an asymptomatic control group. If not corrected this may lead to further PFJ stress and ongoing morbidity.

1. Introduction

Patellofemoral pain (PFP) is one of the most common disorders of the lower limb, often specifically affecting young physically active female athletes [1]. The presence of PFP often limits participation in recreational and sporting activities [2] and, has been linked to the development of patellofemoral osteoarthritis [1,3]. Although the underlying mechanisms are still poorly understood, faulty lower extremity biomechanics and the development of increased knee valgus on limb loading are believed to play a role in the development of PFP [4].

The abnormal lower extremity mechanics are thought to negatively influence alignment of the patella as it passes through the trochlear groove [5]. Noehren et al. [6] showed a significant correlation between knee abduction and external rotation and lateral patella translation when asymptomatic subjects squatted with knees aligned in a valgus or neutral orientation. Wilson et al. [5] found that PFP patients had increased lateral patellar translation and tilt during squatting with the knee aligned in a neutral position. When the load-bearing surface areas are altered, with altered patellar tracking, abnormal distribution of the stresses on the patellofemoral joint will occur [7]. This abnormal distribution of stresses is considered to have a strong correlation with patellar disorders, such as chondromalacia and subsequent osteoarthritis [8], with Tanamas et al. [9] reporting increased lateral patellar tilt being associated with both decreased medial and lateral patella facet cartilage volumes, further adding to increased stress on loading.

Poor limb alignment, specifically an increased knee valgus during single leg squat [10], running [11] and bilateral landing tasks [12] has been associated with PFP. None of the above studies investigated if different movement patterns occurred between different single leg movement tasks and how that relate to the presence of PFP. Therefore, the objective of this study was to assess the knee valgus angle (as defined by the 2D frontal plane projection angle) of female PFP patients and asymptomatic controls while undertaking both a single leg squat and single leg landing tasks. The aim of the study being to establish if female PFP patients single leg land and squat with greater knee valgus than controls and if the nature of the task changes the magnitude of knee valgus. The hypothesis of the study being that the symptomatic knee of the PFP patients would present with a significantly greater knee valgus angle during the unilateral limb loading tasks, which would increase from single leg squat to single leg landing.

2. Materials and method

2.1. Subjects

Thirty asymptomatic female subjects participated in the testing (mean age 20.4±1.4 year, range 18–26 years, height mean 1.66 m

* Tel.: +44 1612952326; fax: +44 1612952395.
E-mail address: L.C.Herrington@Salford.ac.uk.

0968-0160/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.knee.2013.11.011

range 1.60–1.76 m, and weight mean 63.9 kg range 58–68 kg). All participants had no history of anterior cruciate ligament injury or other knee pathology, significant lower limb pathology, lower limb fracture or surgery and had been injury free for 3 months prior to the data collection. Twelve female patients with unilateral patellofemoral pain (age 20 to 38 years (mean 24±3.2 years), height mean 1.64 m range 1.55–175 m, and weight mean 66.9 kg range 57–72 kg) recruited from the host university sports injury clinic, formed the symptomatic comparison group. These participants were examined by an experienced musculoskeletal clinician to establish that they met the required inclusion and exclusion criteria (Table 1) [13], along with only having unilateral pain. All participants participated in at least 3 h of sporting activity per week. Subjects with relatively mild symptoms were chosen to participate in the study to minimize the risk of any symptom aggravation with testing. A written informed consent was obtained from all subjects and the project was approved by the University Research Ethics Committee.

2.2. Procedures

2.2.1. Single leg landing (SLL) task

Subjects were asked to perform a unilateral hop landing task. To orient participants with the task, each subject was asked to perform 3 to 5 practice trials of the task. Once subjects were comfortable with the task, they were asked to perform 3 test trials landing onto their right (dominant in all cases) leg for the control group and both symptomatic and asymptomatic legs for the PFP group. The hop landing task involved the subject hopping off a 30 cm high bench landing with the same leg onto a mark 30 cm from the bench and holding the position on landing for 3 s. While carrying out the task perceived pain was recorded (scored after completion) by the participant marking perceived pain level on a 10 cm visual pain scale (0 equals no pain, 10 worse perceivable pain).

2.2.2. Single leg squat (SLS) task

The procedure for single leg squat involved subjects being asked to stand on the test limb, facing the video camera. Participants were asked to squat down as far as possible, to at least 45° knee flexion but not greater than 60°, over a period of 5 s. Knee flexion angle was checked during practice trials (maximum of three) using a standard goniometer (Gaiam-Pro, Physiomed, Manchester, UK) observed by the same examiner throughout the trials. There was also a counter for each participant over this 5 second period in which the first count initiates the movement, the third indicates the lowest point of the squat and the fifth indicates the end of the movement with them returning to the start position. Trials were only accepted if the subject squats to the minimum degree of knee flexion (45°) and maintained their balance throughout while keeping their hands on their iliac crests [14]. The control group carried out this task on their dominant (right) leg, while the PFP group carried out the task on both legs. While carrying out the task perceived pain was recorded (scored after completion) by the participant marking perceived pain level on a 10 cm visual pain scale (0 equals no pain, 10 worse perceivable pain).

Table 1
Inclusion exclusion criteria for patellofemoral pain patient group (Herrington and Al-Shehri 2007).

Inclusion criteria
• Symptoms of anterior knee pain for at least 1 month
• Average pain level of 3 or more on a 10-cm visual analog scale during stepping up and down of a 30 cm high bench
• Anterior or retropatellar knee pain on at least 2 of the following activities: prolonged sitting, climbing stairs, squatting, running, kneeling, and hopping/jumping
• Presence of 2 of the following clinical criteria on assessment: pain during apprehension test, pain during the patellar compression test, and crepitation during the compression test
Exclusion criteria
• Previous knee surgery or arthritis
• History of patellar dislocation or subluxation, or ligament laxity
• Patellar tendon pathology or chondral damage
• Spinal referred pain
• History of other abnormalities such as leg length inequalities (>2 cm)
• Medication as a part of the treatment
• Previous physical therapy or acupuncture treatment for the knee within the previous 30 days

2.2.3. Video capture

Two dimensional frontal projection plane angle (FPPA) of knee valgus alignment was measured (Munro et al. 2012). A digital video camera (Sony Handycam DCR-HC37, Tokyo, Japan, sampling at 50Hz) was placed at the height of the subject's knee, 3 m anterior to the subject's landing target, and aligned perpendicular to the frontal plane. The digital images were imported into a digitizing software program (Quintic 4, Quintic Consultancy Ltd, Coventry, UK). At this stage the videos were coded so the assessor is blind to the condition. The angle subtended between the lines formed between the markers at the anterior superior iliac spine and middle of the tibiofemoral joint and that formed from the markers on the middle of the tibiofemoral joint to the middle of the ankle mortise was recorded as the valgus angle of the knee. The markers were placed on all participants by the same individual. The angle was captured at the point which corresponded to the lowest point of the landing or squat descent phase. The same individual digitized all the data from all subjects. The average FPPA angle value for both measures from three trials was used for analysis.

The test–retest reliability of this method for assessing an individual's consistency of performance of the knee valgus has been established from our laboratory and has been reported elsewhere [14]. The findings of this study showed good reliability intraclass correlation (ICC) (3,1) = 0.72 (CI (95%) = 0.58–0.89) ($p < 0.001$), with a smallest detectable difference (SDD) of 8.0° for SLS and ICC = 0.82 (CI (95%) = 0.68–0.9) ($p < 0.001$), and SDD 7.8° for SLL.

2.3. Analysis

All statistical analysis was conducted using SPSS for Windows version 16.0 (SPSS Inc., Chicago, IL). The relationship between knee valgus angle during SLL and SLS for both controls and PFP patients was analyzed using a factorial ANOVA 2 factors; task (SLS or SLL) and condition (control, PFP or un-injured). The critical alpha level chosen $\alpha = 0.05$. Paired t-tests were used to evaluate specific differences within conditions and student *t*-test between group comparison with the Bonferroni correction ($\alpha = 0.0125$).

3. Results

In the asymptomatic control group the mean FPPA for SLS was 8.4±5.1° (range 2.5–20.5°), SLL had a mean FPPA of 13.5±5.7° (range 4–26.8°) as shown in Fig. 1. In the PFP group the mean FPPA for SLS was 16.8±5.4° (range 5–22.5°), SLL had a mean FPPA of 21.7±3.6° (range 4–26.8°) as shown in Fig. 1. The FPPA for the uninjured knee of the PFP subjects are also presented in Fig. 1. Table 2 shows the numeric rating pain score for all limbs undertaking the task.

Factorial ANOVA showed no significant interaction ($p = 0.81$ (CI (95%) = 0.73–0.89) between factors. There was a significant effect for both task ($p = 0.005$ (CI (95%) = 0.003–0.007) and condition ($p = 0.001$ (CI (95%) = 0.0006–0.0009). Paired t-tests showed among the control ($p = 0.001$), injured ($p = 0.001$) and uninjured ($p = 0.001$) knees that there was a significant difference in FPPA between tasks. There was also a significant difference between FPPA on SLS between control and injured limb ($p = 0.0001$) and uninjured and injured limb ($p = 0.001$) but not between control and uninjured limb ($p = 0.05$). For SLL FPPA there was a significant difference between control and injured limb ($p = 0.0002$) and uninjured and injured limb ($p = 0.001$) but not between control and uninjured ($p = 0.04$).

4. Discussion

Patellofemoral pain (PFP) is one of the most common disorders of the lower limb, with its greatest incidence in young physically active females [12]. Altered limb alignment involving taking the limb into