ARTICLE

Concentric Hip Muscle Function and Quadriceps-Hamstring Ratio in Athletes with and without Patellofemoral Pain Syndrome

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Abstract

Background: Patellofemoral pain syndrome (PFPS) is a commonly seen condition in athletes. Several potential contributing factors have been postulated. Although hip muscle strength has been suggested to play a major role, concentric hip muscle function in athletes with PFPS has not been formally investigated. **Objectives:** We aimed to compare the concentric hip muscle strength in athletes with PFPS with that of controls, and to derive a concentric knee extension-to-flexion (quadriceps: hamstring) ratio **Subjects and Methods:** University athletes with PFPS (n=25) and asymptomatic controls (n = 25) were studied. Concentric torque of the hip abductors, adductors, flexors and extensors along with concentric knee extensors and flexors torque were assessed. Participants rated their knee pain in the week before the study on a visual analog scale and a self-administered anterior knee pain scale (AKPS). Strength testing was performed at 60°/s. **Results:** Participants with PFPS exhibited much lower concentric hip abduction, adduction, flexion and extension peak torque compared to controls. The concentric hip abduction to adduction and extension to flexion ratios showed no difference. Quadriceps:hamstring ratio was higher for PFPS participants. **Conclusion:** We propose that concentric hip muscle strength is significantly affected in PFPS. Clinicians are urged to include concentric strengthening exercises for the hip along with quadriceps and hamstring muscles during the rehabilitation of athletes with PFPS.

Key Words: Patellofemoral pain syndrome, concentric hip muscle strength, quadriceps:hamstring ratio.

Introduction

Patellofemoral pain syndrome (PFPS) describes a variety of pathologies or anatomical abnormalities leading to a type of anterior knee pain. Patellofemoral pain is an 'umbrella' term used to embrace all peripatellar or retropatellar pain in the absence of other pathologies (1). Patellofemoral pain

syndrome (PFPS) is a common orthopedic knee conditions encountered in athletes particularly in females (1, 2, 3). A widely accepted cause of PFPS is abnormal tracking of the patella within the femoral trochlea (4). This is speculated to be abnormal transverse-plane or frontal-plane (or both) motion of the femur during functional movements (5). Several potential contributing factors that have been suggested include vastus medialis oblique insufficiency, decreased quadriceps, hamstrings and ilio-tibial band flexibility, femoral anteversion, increased quadriceps angle and patellar hypermobility (6-12). Incidence rate of PFPS is 5.4% of the total injuries and as high as 25% of all knee conditions treated at sports injury clinics (13).

Clinically, this syndrome presents as diffuse anterior or retropatellar pain, exacerbated by activities such as ascending or descending stairs, remaining seated for a long time, kneeling, squatting, and during sports activities (6,10). This condition involves the extensor mechanism of the knee, and one of the most commonly accepted causes of PFPS is abnormal tracking of the patella (4).

Concentric muscle contraction produces the joint torque necessary for limb acceleration and facilitates joint motion. To our knowledge, none of the researchers have evaluated concentric torque of hip musculature in athletes with and without patellofemoral pain. Therefore, the purpose of our study was to test for differences between athletes with and without PFPS with regard to concentric hip abduction, adduction, flexion and extension torque as well as to derive a quadriceps: hamstring ratio between the two groups.

Subjects and Methods

Design and settings Study design used was cross-sectional to assess the concentric hip muscle function in athletes with PFPS compared with a control group. Testing was performed at the Human Kinetics Laboratory, Department of Sports Medicine and Physiotherapy, Guru Nanak Dev University. The study was approved by the ethical committee for research, GNDU Amritsar.

Subjects

Fifty university athletes (age range 18-30 years) from different sports (football, gymnastics, cycling, running and field hockey) were randomly selected to participate in the study. The patellofemoral pain group consisted of six female and 19 male participants. Twenty-five age- and body mass matched subjects from the university were used as controls. All subjects were evaluated by the same physician.

Inclusion criteria for the patellofemoral pain group included 1) anterior or retropatellar knee pain present during at least two of the following activities: ascending or descending stairs, hopping or running, squatting kneeling or prolonged sitting; 2) insidious onset of symptoms not related to trauma; 3) pain on palpation of the patellar facets; and 4) worst pain in the past week greater than or equal to 3 cm on a 10 cm visual analogue scale (6). Exclusion criteria for the patellofemoral pain and control groups included 1) history of knee surgery, 2) clinical evidence of other knee injury, or 3) current significant injury affecting other lower extremity joints (15).

For each participant, one limb was used for comparison between the groups. In case of unilateral pain, it was the affected limb that was measured, whereas in participants with bilateral pain it was the patient's self-reported most-affected side that was considered. The corresponding limb of the matched control participant was tested. Before data collection, all participants signed an informed consent duly approved by the institutional ethics committee. Additionally, all participants rated their knee pain in the week before the study on a 10-cm visual analog scale (VAS). Later, a self-administered anterior knee pain scale (AKPS)(14) was completed by the athletes with PFPS to describe their knee function. The AKPS is a 13-item questionnaire with a maximum total score of 100, which indicates no disability. The AKPS has been reported to be valid and reliable (15,16).

Procedures

Before testing, it was duly explained to each participant the aim and procedure of the testing, then an ethically approved informed consent was signed by all involved. After collecting the demographic information, including age, height, and body mass; clinical characteristics, including visual analogue scale (VAS), duration of symptoms, and self administered AKPS indicating measures of knee pain and function were recorded. Each participant completed a submaximal warm-up session consisting of two sets of sit-ups followed by sustained stretching of hamstrings, quadriceps and illiotibial band: two series of 30 seconds with an interval of 30 seconds.

Concentric torque of the hip abductors, adductors, flexors and extensors along with concentric knee extensors and flexors torque were assessed using an isokinetic dynamometer (Kinitech Multi-joint Testing Unit, V5.16, Medisport Engineering, Australia). Before testing, participants were provided with verbal detailed instruction of the testing procedures. Before testing, participants were allowed

three submaximal practice repetitions, for familiarization. Five maximal repetitions for concentric hip abduction, adduction, flexion and extension were collected for each strength test. Strength testing was performed at 60º/s (17). Each participant was provided two minutes of rest between strength tests.

For hip flexion and extension, participants were positioned standing, facing sideways to the frame with corresponding hip adjacent to the pump of the dynamometer. The pelvis of participants was stabilized by the examiner, and the axis of rotation was aligned with the greater trochanter of the femur on the test leg. The lever arm applied resistance to the anterior thigh during flexion and posterior thigh during extension. The non-test leg supported the body of the participant. The participant was instructed to exert maximal strength against the dynamometer in the direction of hip flexion, and then in the direction of hip extension, keeping the knee flexed to 90º. The concentric torque of the hip flexor and extensor was tested simultaneously in the range of 90º of hip flexion to 20º of hip extension.

Hip abduction and adduction torque was assessed with the participant in standing position facing the pump of the dynamometer. The pelvis of the participant was stabilized by the examiner, and the axis of the rotation was aligned medial to the anterior superior iliac spine at the level of the greater trochanter on the test leg. The lever arm applied resistance on the lateral aspect of the distal thigh during abduction, and the medial aspect of the distal thigh during adduction. The non-test leg supported the body of the participant. The participant was instructed to exert maximal strength against the dynamometer in the direction of hip abduction, and then in the direction of hip adduction. Concentric torque of the hip abductor and adductor was tested simultaneously in the range of 30º of hip abduction to 20º of hip adduction.

Knee extension and flexion torque was assessed with the participant in the seated position with the hip and knee flexed to 90º. The upper thigh of the test leg and the trunk was stabilized with straps. The axis of the dynamometer was aligned with the lateral epicondyle of femur. Concentric strength testing for knee flexors and extensors were performed in the range of 90º to 20º of knee flexion.

Statistical Analysis

Prior to analysis, all the variables were analyzed as to normality using the Shapiro-Wilks test. Peak and average torque data for the concentric phases of isokinetic strength testing were determined using Kinitech software (Medisport Engineering, Australia). The average of the middle three trials for each strength test was used for data analysis to eliminate the possibility of learning (trial 1) and fatigue effects (trial 5). We used independent- sample t tests for comparing concentric hip muscle peak torque and average torque values for hip abductors, adductors, flexors and extensors. Similarly the same testing was used for hip adduction to abduction, extension to flexion, and knee extension to flexion ratios. We performed independent-sample t tests to determine difference between demographic variables and for analysis of clinical characteristics i.e. VAS, AKPS and symptom duration Mann-Whitney U test was used. Data were analyzed using the Statistical Package for Social Sciences (SPSS) software (version 14.0). In all analyses, a significance level of $p < 0.05$ was used.

Results

Demographic and clinical characteristics of both the PFPS group and control group are reported in Table 1. The patellofemoral pain group did not differ from the control group on measures of age, height, or mass ($p > 0.05$); however, visual analog scale and AKPS scores indicated that knee pain was present and functional activities were significantly affected in patellofemoral pain group participants.

Results of isokinetic hip torque tests are summarized in Table 2. Participants with PFPS exhibited significantly lower concentric peak torque in hip abduction, adduction, flexion, extension. Results also indicated lower average torque values for hip abduction, adduction, flexion and extension.

Results of comparisons between groups for concentric hip adduction to abduction and extension to flexion torque showed no difference either in abduction to adduction ($t = 0.89$, $p = .37$) ratio nor in extension to flexion ($t = 0.72$, $p = 0.47$) ratio. (Table 3)

Comparison between groups for concentric hip adduction to abduction and extension to flexion torque showed no difference, either in abduction to adduction ($t = 0.89$, $p = .37$) ratio or in extension to flexion ($t=0.72$, $p=0.47$) ratio (Table 3). Results of concentric knee extension and flexion peak torque in PFPS participants were reduced compared to control group (Table 4).

However, concentric knee extension to flexion isokinetic peak torque (quadriceps: hamstring) ratio was higher in the patellofemoral pain group than the control group

Table 1. Comparisons between the patellofemoral pain group and the control group for demographic and clinical characteristics (Mean ±SD).

Characteristics	Patellofemoral Pain Syndrome Group	Controls
Age, y	27.12 ± 2.27	21.80 ± 2.66
Height, cm	171.80 ± 6.56	174.56 ± 8.00
Body mass, kg	62.32 ± 10.18	66.52 ± 7.75
Visual analog scale pain score, cm	5.84 ± 1.06	NA
Anterior knee pain scale score*	67.88 ± 8.42	NA
Symptom duration, month	6.20 ± 5.72	NA

p> 0.05; Not Significant, NA: Not applicable.
* The range of possible scores is 0 to 100.

Table 2. Comparison between the patellofemoral pain group and the control group for concentric hip abduction, adduction, flexion and extension peak and average torque. All the values were high significantly different ($p < 0.001$).

Hip Variable		Patellofemoral Pain Syndrome		Controls	
		Mean ± SD	95% Confidence Interval	Mean ± SD	95% Confidence Interval
Abduction	Peak torque	95.12 ± 35.10	80.63, 109.61	142.76 ± 46.61	123.52, 162.00
	Av. torque	42.00 ± 14.59	35.98, 48.02	65.32 ± 26.24	76.15 54.49,
Adduction	Peak torque	120.32 ± 46.85	100.98, 139.66	211.12 ± 53.62	188.99, 233.25
	Av. torque	62.84 ± 26.39	51.94, 73.74	112.20 ± 30.77	99.50, 124.90
Flexion	Peak torque	118.60 ± 34.01	104.56, 132.64	181.44 ± 51.93	160.00, 202.88
	Av. torque	62.24 ± 22.49	52.95, 71.53	90.12 ± 27.81	78.64, 101.60
Extension	Peak torque	124.96 ± 57.07	101.40, 148.52	198.80 ± 60.43	173.85, 223.75
	Av. torque	67.60 ± 29.59	55.38, 79.82	103.08 ± 32.57	89.63, 116.53

Table 3. Comparisons between the patellofemoral pain group and the control group for abduction:adduction and extension:flexion isokinetic peak torque ratios (Mean ± SD).

RATIO	Patellofemoral Pain Group	Control Group	T	p
Adduction to Abduction	1.40 ± 0.80	1.57 ± 0.47	0.89	.37
Extension to Flexion	1.04 ± 0.36	1.10 ± 0.18	0.72	.47
p> 0.05; Not Significant.				

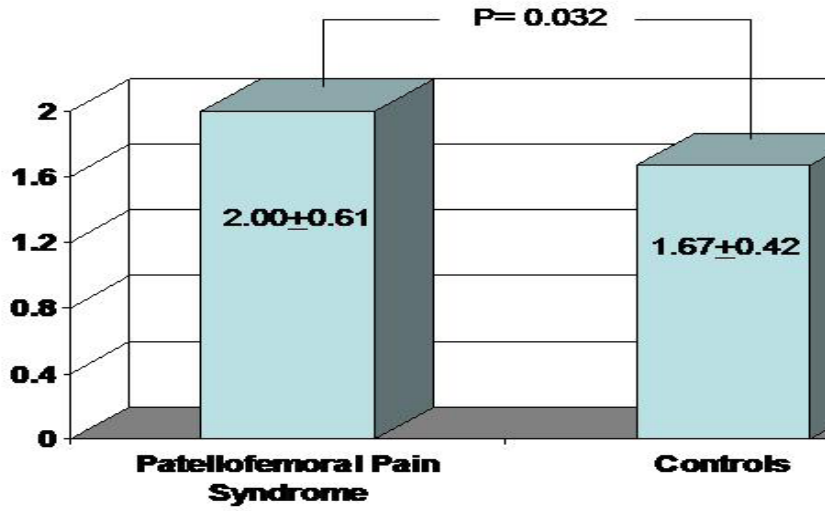
Table 4. Concentric knee extension and flexion peak and average torques (Raw Data) (Mean ± SD)

Knee Variable		Patellofemoral pain Syndrome Group	Control Group
Extension	Peak torque	148.16 ±39.14	202.88 ± 57.91
	Av. torque	77.92 ± 23.94	116.40 ± 29.32
Flexion	Peak torque	79.76 ± 19.85	126.72 ± 38.95
	Av. Torque	50.96 ± 19.85	88.32 ± 36.00

2.00 ± 0.61[95% CI 1.75, 2.26] Vs. 1.67 ± 0.42 [95% CI 1.49,2.21], (t = 2.21, p =.032) (Figure 1).

Discussion

Hip musculature plays an important role in controlling transverse-plane and frontal-plane motions of the femur. Being more precise, weakness of the gluteus medius muscle is believed to increase hip adduction and knee valgus angles, which may be a risk factor for PFPS (5, 10,17). Gluteus maximus, a primary hip extensor, plays an important role in controlling frontal-plane and transverse plane motion of the hip. Weakness of this muscle may lead to malalignment of the patella within the femoral trochlea due to excessive movements of the femur in hip adduction and internal rotation (8,18). Weakness of the iliopsoas can also lead to destabilization of the pelvis developing compensatory anterior pelvic tilt with an internally rotated femur (19, 20). This condition may further lead to increased Q angle, which may produce stress on the patellofemoral joint (8). Few researchers have focused on the role of hip muscle function in the development of PFPS, and the results of those studies have been inconsistent. Based on the functions of these muscles, weakness of the hip muscles may lead to malalignment of the patella within the femoral trochlea due to excessive movements of the femur in hip adduction and internal rotation (18). Previous investigations (14, 21, 22, 23) have reported that individuals with patellofemoral



pain have decreased isometric strength of hip abductors, external rotators, and extensors. Lately, researchers have shown a decrease in strength in eccentric hip abduction, adduction and external rotation in PFPS individuals (4,18). Cichanowski (15) reported global hip muscle weakness, including weakness in hip flexor, extensor, abductor and external and internal rotator muscles in the participants with PFPS. However, the study of Piva, et al. (8), contradicted those results.

We hypothesized that isokinetic concentric torque of the hip muscles would be reduced in athletes with PFPS compared with those without patellofemoral pain. Consistent with the hypotheses proposed, differences in hip muscle function were observed in athletes with PFPS, when compared to pain-free controls. The result of our primary analysis indicated that athletes with PFPS had impairments in hip muscle strength when their symptomatic limb was compared with the corresponding limb of the asymptomatic subjects. The secondary analysis demonstrated a higher quadriceps: hamstring (Q:H) ratio in athletes with PFPS compared to the control group.

Our findings of the isokinetic concentric knee extensors and flexors in athletes with patellofemoral pain concurred with previous research by Goharpey, et al,(28), who reported higher Q:H ratio with reduced mean peak torque for knee extension as well as flexion in the PFPS group compared to controls. The above mentioned findings restate the study of Goharpey, et al (28), which concluded that at low isokinetic speed, the patellofemoral joint is exposed to high external load and a higher magnitude of stress for a longer duration which can lead to quadriceps muscle inhibition. Malone (29) and Dvir (30) stated that due to high eccentric torque and stress in patellofemoral joint, quadriceps inhibition due to pain resulted in reduced knee extensor and flexor peak torque of the PFPS group. No comparisons with the previous findings can be made due to insufficient research. This shows the need for further investigation in this field. Additionally, comparisons could not be made for evaluation of the Q:H ratio in athletes with patellofemoral pain, therefore, this shows the need for future investigation.

Although researchers (2) have reported patellofemoral pain syndrome as the most common knee condition encountered in athletes, we are unaware of any study in which investigators have evaluated the role of hip musculature in athletes with PFPS. Therefore, our purpose was to evaluate concentric hip abduction, adduction, flexion and extension along with knee extension to flexion isokinetic mean peak torque to compare athletes with and without PFPS.

Direct comparisons with previous studies are difficult because no other researchers measured concentric torque of hip in athletes with patellofemoral pain. Our results indicate that concentric hip abduction mean peak torque was 33% lower in the PFPS group than the control group,

whereas Boling, et al (18), observed only an 8% reduction in concentric hip abduction strength. However, our findings for concentric hip abduction torque are similar to previously reported isomeric hip abduction strength studies (16,22,23). Our study also showed a 43% reduction in the concentric hip adduction mean peak torque in PFPS participants compared to controls. This was significantly higher than previous research done by Tyler, et al (9), suggesting only a 6% reduction, while Cichanowski, et al (15), indicated a 16% reduction. A possible reason for conflicting results is the difference in testing procedures. We measured isokinetic torque whereas most of the previous researchers assessed isometric strength. Another possible reason may be alternate methods of positioning participants in different studies. Additionally, athletes with patellofemoral pain in our study were 35% weaker than controls on measures of concentric hip flexion, and 37% weaker on measures of concentric hip extension torque. These findings are significantly higher than the deficit of approximately 14% reported by Tyler, et al (9), and a deficit of 17% indicated by the study of Cichanowski, et al (15), which assessed isometric strength of hip flexors. Boling, et al (18), reported an 8% reduction in concentric hip extension strength in participants with patellofemoral pain compared to healthy controls, Robinson and Nee (22) stated that patients with patellofemoral pain were 52% weaker on measures of isometric hip extension strength than controls. Inconsistency between studies in strength deficits among the concentric and isometric measures in PFPS lends support to the need for further investigation.

The role of hip muscle function in cause and treatment of patellofemoral pain syndrome has received significant attention from various researchers in recent years (8,9,15,16,23,31,32). Based on our findings of decreased hip muscle strength in athletes with patellofemoral pain syndrome, and previous findings of reduction in pain and increased function after strengthening of hip musculature, strengthening exercises for the hip muscles and quadriceps are mandatory in the treatment of patients with patellofemoral pain.

Future investigation is needed to study the relation between concentric and eccentric hip muscle function in athletes with PFPS, and also to determine the relation between the hip muscle weakness and lower extremity kinematics during functional activities in patients with patellofemoral pain.

Athletes with PFPS showed reduced concentric hip abduction, adduction, flexion and extension torque, and also decreased knee extensor and flexor torque compared to the control participants. Based on findings of this study, assessing hip muscle strength is a crucial step in the evaluation of patients with patellofemoral pain. Thus, clinicians and others are urged to include concentric strengthening exercises for the hip along with quadriceps and hamstring muscle strengthening as a part of PFPS rehabilitation protocol for athletes.

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