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Correlation between quadriceps to hamstring ratio and functional outcomes in patellofemoral pain

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ABSTRACT

Background: The aim of this study was to investigate the correlation between quadriceps to hamstring (Q:H) ratio and the functional outcomes in Patellofemoral Pain (PFP) patients.
Methods: The study included forty-four women diagnosed with unilateral PFP. Eccentric and concentric quadriceps and hamstring strength were recorded. Conventional Q:H ratio was calculated as the concentric quadriceps to concentric hamstring peak torque (Ratio 1). Functional ratios were calculated as the eccentric quadriceps to concentric hamstring peak torque (Ratio 2) and as the concentric quadriceps to eccentric hamstring torque (Ratio 3). Functional levels of the patients were determined by using Kujala scores, hop test and step test. Pain levels during activities were recorded. The relationship among Ratio 1, Ratio 2 and Ratio 3 with functional outcomes and pain levels were evaluated using Spearman's correlation coefficient test.
Results: Eccentric and concentric quadriceps and hamstring strength were lower on involved side than uninvolved side. Ratio 2 correlated stronger with Kujala score ($r = 0.69$) than Ratio 1 ($r = 0.49$) and Ratio 3 ($r = 0.30$). Step test ($r = 0.35$) and hop test ($r = 0.38$) only correlated with Ratio 2. Pain levels correlated more with Ratio 2 (r values ranged between 0.38 and 0.48).
Conclusion: Eccentric quadriceps to concentric hamstring ratio was observed more related to the functional outcomes and painful activities in patients with PFP.
Level of evidence III: Cross-sectional study.

1. Introduction

Patellofemoral pain (PFP) is a common knee problem characterized by anterior knee pain. Although the reason of PFP is multifactorial, one of the most important causes of the pain is associated with biomechanical disorders [1–3]. The biomechanical disorders are characterized by the deficit of dynamic stability due to the muscular dysfunction in lower extremity [1–5].

Patellofemoral pain can cause significant pain and dysfunction leading to limitations in daily activities [6–8]. Patients with PFP usually demonstrate pain during ascending/descending stairs, prolonged sitting and squatting, which is associated with the knee muscle dysfunction [7]. The quadriceps muscle is often weakened in patients with PFP and the decreased quadriceps torque, especially in eccentric knee extension, is found to be associated with the PFP [5,7,9,10]. Besides imbalance between quadriceps and hamstring muscle is shown in patients with PFP [10,11]. This muscle imbalance usually depends on a weakened quadriceps muscle but a normal strength of the hamstrings, which subsequently results in a lower quadriceps:hamstring (Q:H) ratio [10,12].

The Q:H ratio has been used not only to examine the similarity between quadriceps and hamstring strength but also to assess knee functional ability and muscle balance [13–15]. This ratio has conventionally been expressed as concentric quadriceps to concentric hamstring strength (Qcon:Hcon) [16,17]. The conventional ratio is reported to be between 1.33 and 1.53 in patients with PFP [10,11] while the corresponding values in healthy subjects is about 1.66 to 2.0 [11,13,18,19]. The functional ratio is the measure of eccentric agonist peak torque relative to concentric antagonist peak torque such as eccentric quadriceps to concentric hamstring strength (Qecc:Hcon) or concentric quadriceps to eccentric hamstring strength (Qcon:Hecc). The functional ratio is proposed as an improved measure of the agonist:antagonist relationship between the quadriceps and hamstring muscles compared to the conventional ratio [18,20]. Although it is believed that the functional ratio directly represents the functional activities, there is no evidence how these ratios change in patients with PFP.

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The activities comprise the combination of eccentric quadriceps to concentric hamstring contractions such as kneeling, squatting and descending stairs which are mostly painful in patients with PFP. Thus, the strength relationship between eccentric quadriceps to concentric hamstrings should be taken into account to determine the knee muscle strength imbalance in PFP [7,11,21]. To the best of our knowledge there is no study in the literature to show whether Q:H ratios relate to knee function in patients with PFP or not. Therefore the first hypothesis of this study was that if there were correlation between conventional ratio (Qcon:Hcon) and functional ratios (Qecc:Hcon and Qcon:Hecc respectively) with the measures of function. The second hypothesis was the correlation between Qecc:Hcon ratio and measures of function were stronger compared to the other ratios.

2. Material and method

A cross-sectional design was used to define the relationship between three different Q:H ratios with the measures of function of patellofemoral pain patients. The conventional ratio and functional ratios including Qcon:Hcon, Qecc:Hcon and Qcon:Hecc were calculated with an isokinetic dynamometer.

Forty-four female patients (mean ± SD, age: 31.5 ± 7.1 years, BMI: 23.9 ± 3.8 kg/m^2) who were diagnosed with unilateral PFP were included in this study. Subjects were assessed by an experienced orthopedist for patellofemoral joint symptoms such as pain reproduced with stair climbing, kneeling, prolonged sitting or squatting or if they had lateral or medial patellar facet tenderness on palpation or a positive patellar compression test. Pain must have been present daily for the previous three months and the pain had to be sufficiently severe for a nominated aggravating activity to a score of four or above on a 0 to 10 cm visual analogue scale (VAS). The subjects who were between 20 and 40 years of age were included in the study. Each subject serves as their own internal control, using the uninvolved side for comparison.

Subjects were excluded if they had a previous patellar fracture or patellar realignment surgery, acute meniscal or ligament injury, osteoarthritis, rheumatoid arthritis or other forms of inflammatory arthritis. Subjects were informed about aims of the study and the testing procedure prior to their participation. Written informed consent and the ethical approval for the study were obtained.

2.1. Muscle torque assessment

Peak concentric and eccentric knee extensor and flexor torques were determined at 60°/s, and 180°/s with the use of Biodex System 3 Dynamometer (Biodex Corp., Shirley, NY, USA) [11]. The dynamometer was calibrated according to the manufacturer's instructions prior to each testing session. The subjects seated upright with an 85° hip flexion and the knee angle set at 90° flexion. The length of the dynamometer arm, which was fastened to the distal portion of the tibia by a velcro strap, was adjusted according to subject's leg length. The monitor was placed in such a way to allow the visual feedback. The range of motion (ROM) for the knee extension and flexion movements was set from 20° to 90° which represents a total of 70° ROM to prevent the elevation of the patellofemoral reaction forces during testing. Prior to testing, the participants were familiarized with the equipment and protocol before completing three submaximal voluntary concentric knee extension and flexion muscle actions and 10 repetitions at 120°/s was applied for warm-up.

For eccentric knee extension subjects were asked to resist the powered knee flexion movement, conversely for eccentric knee flexion, subjects were asked to resist the powered knee extension movement as hard as they could and then relax. For concentric knee extension, subjects were instructed to kick out as hard and fast as possible to full extension; for concentric knee flexion subjects were instructed to pull as hard and fast as possible to full flexion and then relax. Ten repetitions were applied for each speed and the highest torque was recorded. To prevent the muscle fatigue, the 180°/s angular speed was performed before 60°/s for concentric strength testing, the procedure was vice versa for eccentric strength testing [22,23]. A five-minute rest period was given between each cycle with concentric actions and eccentric actions All subjects were encouraged to give a maximal effort for each action by using verbal encouragement.

2.2. Quadriceps to hamstring ratio

The Quadcriceps to Hamstring ratios were calculated as Ratio 1, Ratio 2 and Ratio 3. Ratio 1 was calculated by dividing each subject's concentric quadriceps peak torque by the concentric hamstring peak torque (Qcon:Hcon). Ratio 2 was calculated by dividing each subject's eccentric quadriceps peak torque by the concentric hamstring peak torque (Qecc:Hcon). Ratio 3 was calculated by dividing each subject's concentric quadriceps peak torque by the eccentric hamstring peak torque (Qcon:Hecc). All ratios were calculated at 60°/s and 180°/s velocities and those speeds were chosen because they represent slow and fast isokinetic velocities which have been previously used to evaluate Q:H ratio [13,18,20].

2.3. Pain level and functional outcome assessment

Visual analogue scale with end range descriptors of 0 = no pain, and 10 = extreme pain (0 to 10 cm) was used to assess pain that patients experienced during stair ascent, stair descent, squatting, and prolonged sitting with knees flexed 90°. Also, the pain levels were assessed during isokinetic testing. The 13-item Kujala patellofemoral disorder score was used to determine subject's perceived knee function capability [24]. The step down test was assessed by counting the number of steps down that the patient could perform by using a 25-cm step until the onset of patellar pain [25]. For the hop test, the patients stood on the leg to be tested, hopped, and landed on the same limb. The uninvolved leg was tested first, followed by the involved leg. After the three repetitions were completed, the mean distance hopped was measured and recorded [26].

2.4. Statistical analysis

Data were visually analyzed with histograms, Q–Q plots and Kolmogorov–Smirnov tests for normality of distribution and all data were analyzed with the Statistical Package for the Social Sciences (SPSS Inc., Chicago, IL., USA)) version 17.0. Since Q:H ratios and muscle peak torques were normally distributed, paired sample *t* test was used to compare differences between the involved knee and the uninvolved side. All p values were one-sided with statistical significance set at 0.05 alpha level. The Kujala score, hop test, step test results and pain levels were not normally distributed. The relationships among muscle peak torques, Ratio 1, Ratio 2 and Ratio 3 with Kujala score, step test, hop test and pain levels were evaluated using Spearman's correlation coefficient using two-sided significance of p values, with calculated mean values and standard errors.

3. Results

The mean demographics, pain levels and measures of function of the patients were presented in Table 1. The patients did not indicate any knee pain during isokinetic strength testing.

The eccentric and concentric peak torques of both quadriceps and hamstring muscles were lower on the involved compared to the uninvolved side at 60°/s and 180°/s (Table 2). While, Ratio 1 and Ratio 2 were found lower on the involved side at 60°/s, and 180°/s when compared to uninvolved side, Ratio 3 was found higher on the involved side at both angular speeds (Table 2).

The relationships between peak torques with the pain levels and functional tests were summarized in Table 3. The eccentric quadriceps (r value ranged between 0.26 and 0.37) and concentric hamstring (r value ranged between 0.26 and 0.36) peak torques were significantly correlated with pain levels during stair descending, squatting and sitting (Table 3). Kujala score (r value ranged between 0.24 and 0.67) was correlated with all peak torques at 60°/s angular speed (Table 3). Step test (r value ranged between 0.23