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Are there differences in Knee Stability between Patients with Patellofemoral Pain and Healthy Subjects during a Slow Step Descent Task?

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Abstract

Objectives

To date no study exists to determine whether knee kinematics in the coronal and transverse planes during step descent are different between healthy subjects and patients with patellofemoral pain (PFP) despite patients often reporting pain and instability during this task. This study investigated the differences in knee kinematics between healthy subjects and patients with PFP during a step descent task.

Methods

Thirty healthy subjects and 29 patients diagnosed with PFP performed a slow step descent from a 20cm step. Kinematic data were collected using a ten camera infra-red motion analysis system. Reflective markers were placed on the foot, shank and thigh using the Calibrated Anatomical Systems Technique (CAST).

Results

The coronal plane knee range of motion (ROM) was 2.7 degrees, 41% greater, in the PFP patients compared to healthy subjects (p=0.006), with 4 degrees greater internal rotation although this was not significant (p=0.087). A trend towards significance was also seen between males and females (p=0.059), with females having a greater ROM in the transverse plane than both the healthy subjects and male patients, with females with PFP showing the greatest ROM.

Conclusions

This study further reinforces the view that coronal plane mechanics should not be overlooked when studying PFP. Future research should focus on developing more clinically viable techniques that can provide clinicians with reasonable estimates of coronal plane knee kinematics during various functional tasks, this may help identify important clinical subgroups and responders and non-responders to different interventions.

Keywords:

patellofemoral pain; step descent; biomechanics; clinical assessment; stability

INTRODUCTION

The latest systematic review and meta-analysis by Smith et al (1) confirms the high incidence and prevalence rates of Patellofemoral Pain (PFP) of up to 14.9% and 28.9% respectively across a number of populations including military recruits, amateur runners and adolescent amateur athletes. However, despite this high prevalence currently there is no consensus of the best management for PFP, and a wide range of treatments have been suggested including foot orthoses, patellar taping, knee supports and physiotherapy (2,3). Little data exists which allows a clear distinction in the biomechanical presentation between individuals with and without PFP. Selfe et al. (4) recently identified three subgroups in a cohort of 127 PFP patients: 'weak and tight' (39%), 'weak and pronated' (39%), and 'strong' (22%). The two largest subgroups were both classified as having weak quadriceps and weak hip abductor muscles. The hip abductor muscles play a key role in pelvic control during gait and dysfunction of this muscle group can predispose to patellofemoral pain (5,6,7,8), as hip abductor weakness can lead to increased femoral adduction, which produces a dynamic valgus collapse which in turn is believed to increase the lateral force acting on the patella (9). Research focusing on runners with PFP, confirms that PFP sufferers have 3.5° greater hip adduction than healthy controls (10).

Nakagawa et al. (11) studied eighty recreational athletes equally divided into four groups: male and female PFP subjects, and male and female controls. Trunk, pelvis, hip, and knee frontal plane kinematics and activation of the medial gluteal muscle were evaluated at 15°, 30°, 45°, and 60° of knee flexion while ascending and descending a step normalized to 10% of participant height. Additionally, isometric hip abductor torque was evaluated. During step descent PFP subjects demonstrated increased knee abduction at all angles and the female PFP group demonstrated lower hip abductor torque compared to the

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other groups. Results showed there was a significant increase in lateral patellofemoral joint loading, during knee flexion, in subjects with PFP compared to a control group.

Selfe et al. (12,13) highlighted that a dynamic "challenge" for the knee is needed to explore the effect of different treatment options in people with PFP. They proposed that a 20 cm slow step descent increased eccentric control, as the knee in a closed kinetic chain moves from a relatively stable to an increasingly unstable position whilst having to resist the acceleration of the participants body weight towards the ground. They reported reductions in the range of coronal and transverse plane angles and moments, when using knee taping and soft bracing, which was purported as an improvement in knee joint control. However, to date no study exists to determine whether knee kinematics in the coronal and transverse planes during step descent are different between healthy subjects and patients with PFP despite patients often reporting pain and instability during this task.

METHODS

Participants

Thirty healthy subjects and 29 patients clinically diagnosed with PFP were recruited. All volunteers gave written informed consent prior to data collection. The study was approved by the Research Ethics Committee, University of Central Lancashire and Cumbria and Lancashire NHS Ethics Committee (REC reference number 07/Q1309/2). The patients were clinically diagnosed with PFP and had been referred to a Primary Care musculoskeletal physiotherapy service. Eligibility for the study was determined by clinical examination. Inclusion criteria were; aged between 18 and 40 years, presence of traumatic or idiopathic peripatellar pain and pain provoked by one of the following alone or in combination: deep squatting, kneeling, ascending or descending stairs. An exclusion criterium was any history of knee surgery. Patients meeting these eligibility criteria were physically examined to exclude referred pain from the spine, pelvic region and hip joint, leg length discrepancy, knee ligament, quadriceps tendon and meniscal pathology, Hoffa's and medial plica syndrome, femoral anteversion, and tibial torsion. Healthy subjects were included if they were aged between 18 and 40 years and were excluded if they had been previously diagnosed with any lower limb musculoskeletal injuries or had a history of surgery to the lower extremities.

Procedures

Five repetitions of a 20 cm slow step descent were performed. The purpose of the step descent was to assess the control of the knee as the body was lowered as slowly as possible from the step (12, 13, 14). Kinematic data were collected using a ten camera infra-red Oqus motion analysis system (Qualisys medical AB, Gothenburg, Sweden) at 100 Hz. Passive retro-reflective markers were placed on the lower limbs using the Calibrated Anatomical System Technique to allow for segmental kinematics to be tracked in 6-degrees of freedom. Reflective markers were positioned on the anterior superior iliac spine, posterior superior iliac spine, greater trochanter, medial and lateral femoral epicondyles, medial and lateral malleoli, the medial aspect of the head of the 1st metatarsal, the lateral aspect of the head of the 5th metatarsal, the dorsum of the foot and the calcaneus. Additionally, clusters of four non-collinear markers were attached to each of the body segments. Raw kinematic data were exported to Visual3D (c-motion Inc., USA) and filtered using a low-pass, fourth order Butterworth filter with a cut off frequency of 6 Hz. Anatomical frames were defined by landmarks positioned at the medial and lateral borders of each joint, from which right-handed segment co-ordinate systems were defined. Joint kinematics were calculated relative to the shank coordinate system. The kinematics were calculated based on the cardan sequence of XYZ, equivalent to the joint co-ordinate system proposed by Grood and Suntay (15). Maximum, minimum and range of knee angles in all three planes were quantified from the toe off of the contralateral limb to initial floor contact of the contralateral limb, providing data for the supporting painful limb or dominant limb during descent.

Statistical analysis

Data were examined for normality using Shapiro-Wilk tests and found suitable for parametric testing. Two factor ANOVAs were performed to explore the differences in knee angles between patients and healthy subjects and males and females for the maximum, minimum and range of motion (ROM) in the sagittal, coronal and transverse planes. Significance was set to $p \leq 0.05$.

RESULTS

No significant interactions were seen between the two groups and gender for any variables. Significant differences were seen between the healthy subjects and patients with patellofemoral pain for the ROM in the coronal plane during the slow step-down tasks. The patients showed a 2.7 degree or 41% greater varus-valgus ROM (p=0.006), and a 4 degree or 100% greater internal rotation of the knee than their healthy counterparts, although the latter was not significant due to variance within the data (p=0.087). No other parameter showed any differences or trends towards a difference between PFP patients and healthy subjects. In addition, it should be noted that standard deviations for the ROM were more than half the values for the maximum and minimum measurements for the coronal and transverse plane

Table 1: Knee joint angles and ranges of motion (ROMs), means (standard deviations)

Joint angles	Health volunteers		Patients with patellofemoral pain	
	Men	Women	Men	Women
Max flexion	83.8 (6.7)	83.4 (8.5)	80.7 (6.3)	85.8 (8.7)
Max extension	17.2 (6.1)	17.3 (8.5)	18.5 (4.7)	20.7 (8.2)
Sagittal plane ROM[1]	66.6 (6.4)	66.1 (10.0)	62.2 (7.3)	65.1 (9.3)
Max valgus	-4.5 (7.0)	-4.8 (4.4)	-4.9 (4.5)	-7.0 (7.7)
Max varus	1.8 (7.6)	1.9 (4.2)	3.9 (6.5)	3.1 (6.4)
Coronal plane ROM[1]	6.4 (3.1)	7.0 (2.6)	8.8 (4.0)	10.1 (4.1)
Max external rotation	-4.2 (9.6)	-1.6 (5.8)	0.9 (7.9)	-1.0 (7.0)
Max internal rotation	2.4 (10.5)	5.5 (5.1)	7.2 (8.5)	8.8 (7.4)
Transverse plane ROM[1]	6.9 (3.7)	7.4 (3.3)	6.2 (3.2)	9.8 (4.4)

[1] Range on motion

movement patterns. This indicates greater variation in peak measures of varus/valgus and internal/external rotation than the total motion excursions, Table 1 and 2. Females with PFP had a greater ROM in the transverse plane than both the healthy subjects and male patients, however no significant difference was seen although a trend towards significance was seen between males and females, with females showing greater transverse plane ROM (p=0.059).

Table 2: Differences between healthy volunteers and patients with patellofemoral pain and between genders

	Mean Difference	*p*-value	95% Confidence interval
Healthy volunteers vs. patients with patellofemoral pain			
Maximum flexion	0.3	0.877	-3.8 to 4.4
Maximum extension	-2.3	0.223	-6.2 to 1.6
Sagittal plane ROM[1]	2.7	0.242	-1.8 to 7.2
Maximum valgus	1.3	0.438	-2.1 to 4.7
Maximum varus	-1.6	0.355	-5.0 to 1.8
Coronal plane ROM[1]	-2.7	0.006	-4.6 to -0.8
Max external rotation	-2.9	0.193	-7.3 to 1.5
Max internal rotation	-4.0	0.087	-8.6 to 0.6
Transverse plane ROM[1]	-0.8	0.434	-2.9 to 1.3
Men vs. women			
Maximum flexion	-2.4	0.253	-6.5 to 1.7
Maximum extension	-1.2	0.532	-5.0 to 2.6
Sagittal plane ROM[1]	-1.2	0.605	-5.7 to 3.3
Maximum valgus	1.2	0.474	-2.2 to 4.6
Maximum varus	0.3	0.84	-3.1 to 3.8
Coronal plane ROM[1]	-0.9	0.331	-2.8 to 1.0
Max external rotation	-0.4	0.87	-4.7 to 4.0
Max internal rotation	-2.3	0.312	-6.9 to 2.3
Transverse plane ROM[1]	-2.0	0.059	-4.1 to 0.1

[1] Range on motion

DISCUSSION

In this study, knee kinematics were compared during a slow step descent in patients with PFP and asymptomatic controls. Consistent with our proposed hypothesis patients with PFP showed a greater ROM at the knee in the coronal plane than their healthy counterparts. Specifically, PFP subjects demonstrated a 2.7 degree or 41% greater coronal plane knee ROM than controls during the stepdown task which may indicate altered motor control or increased knee instability. This is in agreement with the recent findings by Burston et al. (16) who found significant differences, albeit not to the same magnitude, between PFP patients and healthy subjects in coronal plane knee ROM during normal speed stair descent, and Wilson et al (10) who showed a similar magnitude of difference for hip adduction. It has been proposed that increased patellofemoral joint (PFJ) stress contributes to PFP development (17) and according to Huberti and Hayes (18) a 10 degree increase in Q-angle can cause a 45 percent increase in PFJ stress. The coronal plane knee instability demonstrated by the PFP subjects in this study could lead to an increased dynamic Q-angle, excessive PFJ loading, and PFP provocation. Consistent with this premise, Chen et al. reported that the laterally directed component of the resultant patellofemoral joint reaction force experienced by PFP subjects was more than twice the magnitude of that experienced by control subjects during stair descent (19). Thus, coronal plane knee kinematics may be considered as a marker that clinicians should assess when evaluating patients with PFP.

With respect to coronal plane knee angles measured at discrete points, i.e. minimum and maximum values, our hypothesis was not confirmed as there were no group differences. However, the female patients did demonstrate a greater movement into valgus of 7 degrees. This finding is in contrast to a study by Nakagawa et al. (11) who reported that subjects with PFP demonstrated increased knee abduction compared to asymptomatic control subjects at various knee flexion angles during a step descent task. These contrasting findings may be explained by some important methodological differences. The knee abduction angles reported by Nakagawa et al. were calculated as the difference in knee angle observed during static standing from that observed during the single leg step down. It is possible their reported differences were caused by different static standing knee postures for each group, whereas in our study knee kinematics were not normalized to static standing posture and thus would not have been sensitive to different static standing postures (if present). Additionally, Nakagawa et al. examined coronal plane kinematics at discrete knee flexion angles up to 60° flexion, whereas in the current study the peak knee flexion for subjects in both groups was 83°. The greater knee flexion angles experienced from a standard step height would produce greater knee moments and therefore lead to greater patellofemoral loading.

In contrast to coronal plane group differences sagittal and transverse plane knee kinematics were similar for both groups, although the female PFP patients did show greater values. Previous studies have reported similar findings in the sagittal plane when examining stair descent. For example, Salsich et al. (20) and Heino-Brechter et al. (17) reported there were no differences in knee flexion kinematics during stair descent for subjects with PFP compared to controls. More recently, Bolgla et al. (21) found that PFP subjects demonstrated similar sagittal and transverse plane kinematics compared to asymptomatic control subjects during stair descent. Such findings suggest that the sagittal and transverse planes are less sensitive to the differences between groups than the coronal plane kinematics.

The increased coronal plane knee ROM among PFP subjects is suggestive of greater knee joint instability, which may contribute to excessive PFJ loading and PFP onset and/or exacerbation. This is clinically important as previous studies have reported that excessive coronal plane knee ROM in patients with PFP is a modifiable factor, which can be minimized with taping and bracing interventions (12,13). Additionally, for some individuals, the use of such interventions has been associated with improved PFP symptoms (22). Thus, taken as a whole, these findings justify the need for clinicians to identify and address excessive coronal plane knee ROM when managing PFP patients.

In order to address abnormal coronal plane knee kinematics, clinicians must have an objective means of assessment. A common technique used to obtain reliable and valid measures of coronal plane knee kinematics involves sophisticated equipment and procedures, i.e. a 3D motion capture system and biomechanics laboratory. However, such equipment and procedures are not practical for broad-based clinical use. Recent technological advances have enabled the development of mobile device applications that allow users to record 2D digital video from which kinematics and other performance-related variables can be assessed (23). Although promising, there is a paucity of research examining the reliability and validity of these mobile device applications for clinically assessing movement kinematics. In addition to 2D video analysis via mobile device applications, another recently developed technique involves the use of Inertial Measurement Units (IMUs) to assess stability. Budini et al. (24) reported that it is possible to detect changes in lower limb stability whilst performing the Y-balance test when using taping and bracing from IMU angular velocity data, using only two sensors placed on the lateral aspect of the shank segments. Although detected in healthy subjects, these changes may be clinically relevant and should be examined in various patient populations.

Future research should focus on examining the reliability and validity of clinically viable techniques, such as mobile device applications and IMUs, which can provide clinicians with a quick, relatively inexpensive, and objective assessment of coronal plane knee stability during various functional tasks that may aid in the decision-making process.

CONCLUSIONS

Coronal plane knee ROM is significantly greater in PFP subjects compared to their healthy counterparts and demonstrates a potentially clinically important difference of 41%. This finding is suggestive of increased knee joint instability which could contribute to excessive PFJ loading and PFP onset and/or exacerbation. As such this variable could be considered as a clinical marker to allow objective documentation of movement dysfunction and treatment effectiveness for PFP patients. Future research should focus on developing more clinically viable techniques that can provide clinicians with reasonable estimates of coronal plane knee kinematics.

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