EFFECT OF PAIN ON HIP AND KNEE KINEMATICS DURING A PROLONGED RUN IN FEMALE RUNNERS WITH PATELLOFEMORAL PAIN SYNDROME

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The purpose of this study was to investigate hip and knee mechanics during a prolonged run in individuals with patellofemoral pain syndrome. Kinematic data was collected from 8 female recreational runners currently suffering from the condition and 7 controls during a prolonged treadmill run. Runners with patellofemoral pain syndrome did not appear to display altered running mechanics in the presence of significant pain or exertion, but did display differences in mechanics compared with controls, with two distinct subgroups identified. This finding might suggest two distinct mechanisms of injury for patellofemoral pain syndrome. This knowledge is important for establishing clear links between running mechanics and injury mechanisms and can be used to inform injury prevention and rehabilitation techniques.

KEY WORDS: Fatigue, knee valgus, knee abduction, hip adduction.

INTRODUCTION: Patellofemoral pain syndrome (PFP) is the most prevalent musculoskeletal injury amongst runners (Taunton et al., 2002), with females twice as likely to be affected as males (Boling et al., 2010). The condition is characterised by very little or no pain at the beginning of a run, with pain progressively worsening, often leaving the runner unable to continue (Dierks et al., 2011). Understanding the running mechanics associated with PFP is important in indentifying those at risk and designing interventions aimed at reducing the incidence of this condition.

Faulty running mechanics are believed to be a contributing factor to PFP. Unique frontal and transverse plane kinematics have been reported in individuals with PFP, with greater peak knee abduction (Bazett-Jones et al., 2013), peak hip adduction and peak hip internal rotation than matched controls (Noehren et al., 2012a). Increased movement proximal to the knee at the hip has been suggested to result in greater knee abduction, with increased dynamic knee valgus proposed as a mechanism for PFP through increased lateral tracking of the patella (Powers, 2010). Excessive hip adduction and internal rotation has been attributed to muscular weakness. Dierks et al. (2008) reported a relationship between hip abductor weakness and peak hip adduction angle, with this relationship found to be stronger towards the end of a prolonged run.

Given the gradual onset and progression of pain throughout a run, recent studies have investigated the relationship between pain, fatigue and running mechanics in individuals with PFP (Bazett-Jones et al., 2013; Dierks et al., 2011; Noehren et al. 2012b). Noehren et al. (2012b) found that female runners with PFP did not alter their running mechanics in the presence of pain, but found greater hip adduction and hip internal rotation at the beginning of the run compared with controls. However, Dierks et al. (2011) found lower peak hip adduction in a group of male and female runners with PFP compared with a control group. Further analysis revealed three distinct PFP sub groups, those who displayed a knee abduction movement, those who displayed a hip abduction movement and those who displayed a typical knee and hip adduction movement. These findings suggest that runners with PFP display altered knee and hip mechanics which might relate to different injury or compensatory mechanisms. Given the paucity of research in this area and the conflicting findings to date, the association between pain, exertion and mechanics in runners with PFP, warrants further investigation.

The purpose of this study was to investigate hip and knee mechanics during a prolonged run in those with PFP. Specifically, we aimed to establish if differences existed between participants with and without PFP in frontal and transverse hip and knee mechanics across the course of a run. A subsidiary aim was to establish if the onset of significant pain was associated with altered mechanics in those with PFP.

METHODS: After institutional ethics approval, eight recreational female runners currently suffering from PFP were recruited (35±12 years, 64.6±5.2 Kg, 1.65±0.05 metres, 21±10 miles per week). All participants were initially screened by a qualified physiotherapist to confirm their eligibility for the study. To qualify for the study all participants were required to run at least 10 miles per week and have been suffering from PFP for a minimum of two months before data collection, rating their pain during running as at least 3 on a 0 (no pain) to 10 (maximum pain) self reported pain scale. A control group (CON) from the same recreational running population comprised seven participants who were currently free from lower extremity injury and ran at least 10 miles per week (43±6 years, 62±4.5 Kg, 1.66±0.06 metres, 17±7 miles per week). ±

Reflective markers were placed on the participant's lower limb to define a three segment model adapted from Ferber et al. (2002), comprising the pelvis, upper leg and lower leg. In the case of unilateral pain the affected limb was tested and in the case of bilateral pain, the limb with the highest pain scored was tested. For the CON group, the right leg of each participant was tested. All three dimensional kinematic data were collected using a 12 camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA, USA) sampling at 200 Hz.

Participants were required to complete a treadmill run at a self-selected speed while wearing the same neutral laboratory running shoes. Heart rate was recorded for every minute of exercise and the participant was required to state their relative perceived exertion and perceived level of pain for each minute during the run. The run terminated when the participant reached either 85% of their heart rate maximum, reached a score of 17/20 on the perceived exertion scale (Borg, 1998), or reached 7/10 on self-reported pain scale. Kinematic data were collected for the first 10 seconds of every minute throughout the run, with three time points analysed; the first minute, the onset of significant pain and the last minute of the run. The onset of pain was identified as the minute where the PFP participants identified their pain as a 5 on the self-reported pain scale.

Three-dimensional coordinate data were low-pass filtered and joint angles calculated for the hip and knee relative to the proximal segment. All angles were normalised to a static standing trial and cropped to stance for each foot strike using the vertical position of a heel marker to define foot strike and peak knee extension to define toe off (Fellin et al., 2010). Kinematic variables of interest included peak knee internal rotation, peak knee adduction, peak hip internal rotation and peak hip adduction. These variables were determined as the maximum values that occurred during stance. All variables were calculated based on 5 running cycles for each of the three time points. At the onset of pain for PFP participants, CON participants were matched with data taken at the same time point. Visual inspection of those participants in the PFP group revealed two distinct subgroups, those who displayed knee adduction through the first half of stance (PFPnormal) and those who displayed knee abduction during the first half of stance (PFPkabd). As such, these subgroups were analysed separately with peak angles for these subgroups compared with the CON group. Cohen's d values were used as a measure of effect size (ES), with only large ES (ES>0.80) considered clinically meaningful.

RESULTS: Running speed was similar between groups (CON 9.5±1.3Km/hour; PFP 10.1±0.69 Km/hour), but total run time was found to be less in the PFP group (26±11 minutes) compared with the CON group (32±11 minutes). In the PFP runners, the onset of reported pain occurred at 14 ± 6 minutes with the run terminated due to excessive pain in three of the participants and the other five reaching 85% of heart rate. Runners in the PFPnormal group displayed smaller peak angles for knee adduction, knee internal rotation, hip adduction and hip internal rotation, than the CON group (Tables 1 and 2). While displaying a knee abduction movement pattern (Table 1), participants in the PFPkabd group were also found to have a greater peak hip adduction at the start of the run than the CON group (Table 2). No differences in peak angles were seen across the course of the run, with the exception of the PFPkabd group who displayed increased peak hip adduction between the onset of pain and the end of the run (ES=0.99).

Table 1 Group means (SD) for peak knee angles at the start of the run, onset of pain and the end of the run.

Group	Knee Adduction			Knee Internal rotation		
	start	pain	end	start	pain	end
CON (°)	2.9(2.7)	2.8(2.2)	2.9(3.3)	8.0(4.3)	9.6(5.5)	10.7(5.4)
PFPnormal(°)	1.1(1.0)	0.7(2.3) #	-0.1(3.4)#	3.9(4.7) #	4.4(4.1) #	3.8(5.1) #
PFPkabd(°)	-5.6(3.1)*	-6.4(2.4)*	-6.2(2.9)*	5.5(4.8)	6.6(5.5)	5.6(4.3)

Large effect between CON and PFPnorm (ES>0.80). * Large effect between CON and PFPKabd (ES>0.80).

Table 2 Group means (SD) for peak hip angles at the start of the run, onset of pain and the end of the run.

Group	Hip Adduction			Hip Internal rotation		
	start	pain	end	start	pain	end
CON (°)	12.8(5.5)	14.5(4.6)	14.7(3.7)	13.0(6.7)	8.7(5.5)	9.8(3.8)
PFPnormal (°)	9.1(2.0) #	8.1(4.2) #	9.3(4.8) #	1.3(4.0)	3.0(4.5) #	3.9(3.8) #
PFPkabd (°)	15.1(3.1)*	16.2(3.3)	17.9(2.5)	6.2(4.9)	7.2(4.8)	7.1(4.7)*

Large effect between CON and PFPnorm (ES>0.80). * Large effect between CON and PFPKabd (ES>0.80).

DISCUSSION: The aim of this study was to establish if differences exist in frontal and transverse plane hip and knee mechanics over a prolonged run, and if the onset of significant pain was the result of altered mechanics in those with PFP. Interestingly, runners with PFP did not appear to display altered running mechanics in the presence of significant pain or exertion. However, visual inspection of runners with PFP revealed two subgroups who each displayed distinct knee mechanics.

Those runners in the PFPkabd sub group displayed knee abduction throughout the early part of stance, this finding agrees with previous research which reported greater knee abduction in participants with PFP than controls (Bazett-Jones et al., 2013). In addition, this group also showed greater hip adduction at the start of the run than the control group. Therefore, the PFPkabd group would appear to demonstrate frontal plane kinematics more associated with dynamic valgus, a suggested mechanism for PFP (Powers 2010). Previous research has found runners with PFP demonstrate weakness in the hip abductor muscles (Dierks et al., 2008), which might explain the greater peak hip adduction seen in the PFPkabd group at the start of the run. The PFPkabd group displayed increased peak hip adduction between the start of the run and when the run was terminated (all participants in the PFPkabd group terminated the run due to excessive pain). The relationship between hip abductor weakness and peak hip adduction has been found to be greater at the end of a prolonged run (Dierks et al., 2008), suggesting that the increased hip adduction seen in the PFPkabd group in the presence of excessive pain, might be the result of muscular fatigue in the hip abductor muscles.

Those in the PFPnormal group displayed smaller peak angles for knee adduction, knee internal rotation, hip adduction and hip internal rotation, than the control group. This finding is in part supported by Dierks et al. (2011) who found reduced peak hip adduction in runners with PFP. These findings are contrary to the causal mechanism of PFP proposed by Powers et al. (2010) who suggested that greater frontal and transverse plane motions at the hip can increase dynamic knee valgus. Potentially, participants in the PFPnormal group were compensating in an attempt to reduce dynamic misalignment at the knee and delay the onset of pain (Dierks et al., 2011). Since no differences in peak angles were seen across the run in the PFPnormal group, it might be that they used altered hip and knee mechanics from the start of the run to delay the onset of pain. However, Dierks (2011), reported that most joint motions increased at the end of the run when pain and exertion were greatest, whereas the present study found no increase in peak angles in the presence of significant pain or exertion. A potential explanation for this conflicting finding might relate to the criteria used to terminate the run. Interestingly, all five of the runners in the PFPnormal group terminated the run due to excessive exertion (HR> 85% max) rather than excessive pain. In the study by Dierks et al. (2011), 60% of the PFP runners terminated the run due to excessive pain. Therefore, had the run gone on longer, the development of further pain might have resulted in peak angle increases due to these runners being unable to maintain this strategy.

CONCLUSION: This study suggests that female runners with PFP display altered knee and hip mechanics, with two distinct subgroups identified. This finding might suggest two distinct mechanisms of PFP injury. However, the mechanics displayed by some runners with PFP may be indicative of a compensatory strategy aimed at delaying the onset of pain. Further investigation of these sub groups is needed to establish clear links between running mechanics and injury mechanisms. This knowledge will guide the use of injury prevention and rehabilitation techniques such as gait retraining which have been shown to significantly reduce the symptoms of PFP Noehren et al. (2013).

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