TRANSVERSE AND FRONTAL PLANE LOWER LIMB KINEMATICS IN FEMALE RUNNERS WITH PATELLOFEMORAL PAIN

Jacqueline Alderson, Bruce Elliott and David Lloyd
School of Human Movement and Exercise Science, The University of Western Australia, Perth, Australia

Patellofemoral pain syndrome (PFPS), one of the most common disorders in running has been shown to affect females more frequently than males. The aetiology of patellofemoral pain syndrome is not clear but abnormal hip and knee frontal and transverse plane motion are commonly associated with the disorder. This study investigated transverse and frontal plane kinematics and kinetics in female runners symptomatic and asymptomatic for patellofemoral pain. The findings of this study did not reflect the common clinically held association between excessive femoral internal rotation, internal tibial rotation and knee valgus in runners with PFPS. The PFPS subjects displayed greater external hip and external knee rotation compared with asymptomatic runners. The results have identified a different set of mechanical conditions which may affect patella tracking.

KEY WORDS: knee, patellofemoral pain, overuse injury, knee injury

INTRODUCTION: The 2001 Australian Sports Commission's Exercise, Recreation and Sport Survey reported that walking and running ranked 1st and 4th respectively as two of the most popular forms of physical activity for women. There is also little doubt that the popularity of these activities is not confined to Australia, with just over 60% of females over 12 years of age in Canada and the USA, regularly participating in walking and running. However, while researchers and medical practitioners promote the therapeutic and preventative effects of increased exposure to physical activity, there is also agreement that increased participation heightens the risk of injury. For individuals who adopt running as their regular physical activity, this equates to a significant risk in the development of the most common form of running related injury, knee pain (van Mechelen, 1992). PFPS presents as the most common knee pathology with reported incidence rates in runners ranging from 23.2 % (Taunton et al., 1987) to 57.5% (Messier et al., 1991). The only published study specifically investigating femoral rotation in PFPS individuals reported symptomatic subjects had less femoral internal rotation during early stance in walking when compared with a control population (Powers et al., 2002). These preliminary findings indicate that previous biomechanical research may have focussed too heavily on the role of abnormal foot motion and suggests that further investigation of the role of transverse plane thigh and lower leg motion is warranted (Powers, 2003). The purpose of this study was to compare the transverse and frontal plane mechanics of female runners symptomatic and asymptomatic for PFPS.

METHODS: Twenty-nine 20 mm retro-reflective markers were placed on the lower body and all subjects ran at a self selected speed and at 4.0 ± 0.2 $m.s^{-1}$. Seventeen runners symptomatic for PFPS (SYMP) and 17 asymptomatic runners (NONS) ran in their own shoes and were not aware that force platforms lay beneath a carpeted walkway. Adequate rest was provided between all trials, until at least five successful force platform strikes were collected from each leg in both conditions. The marker placement, coordinate system determination and joint centre calculation using a functional modelling approach, allowed for 3D movement of body segments to be measured. Marker coordinate data were filtered using a Woltring quintic spline routine (Woltring, 1986) with a mean squared error of 20. Analog data were filtered in Matlab prior to modelling using a 4^{th} order Butterworth digital filter operating at 10 Hz. Data analyses were conducted in SAS® statistical software Version 6.1. One-way analyses of variance were used to identify significant differences between the NONS and SYMP groups. In order to reduce the likelihood of making a type a type I error Bonferroni adjustments were made to an initial alpha level of <0.05.

RESULTS AND DISCUSSION: On analysis of the left and right limb data, no significant within group differences were evident resulting in the pooling of left and right limb data for further statistical analysis. Data were analysed at foot strike, toe off and across the entire stance phase.

At the pelvis, no differences were found in peak pelvis tilt, obliquity or rotation angles although the range of frontal plane pelvic motion was significantly higher in the SYMP group (12.2°) when compared with the NONS runners (10.9°). Furthermore, the rate of pelvic drop was significantly higher in the SYMP group (-124.8°/s) compared with the NONS (-111.1°/s). This finding lends support to the clinical theory that PFPS symptomatic individuals have poor hip and pelvic musculature strength (Ireland et al., 2003; Mascal et al., 2003).

The most significant finding at foot contact was that the SYMP group displayed a mean 6.8° of knee (lower leg) external rotation compared with the 2.7° recorded for the NONS runners. Both groups were in a position of ≈2° internal hip rotation at foot contact. Consequently, an overall 4.5° phase difference in the transverse plane position of the hip and knee (hip-knee separation angle) was exhibited in the NONS group, while the difference in the SYMP runners was more than twice the amount at 9.4°.

No differences were observed between the NONS and the SYMP runners for peak hip abduction angle (9.4° and 11° respectively) or peak hip adduction angle (12.6° and 11.9° respectively) across stance. The similar levels of peak hip adduction is in contrast to the findings of McClay et al. (2003), who reported that symptomatic runners had a 3° significantly higher peak hip adduction angle when compared with healthy runners (9.4° v 6.7° respectively). At 20% of stance, the peak hip adduction angular velocity of the SYMP group (80.3°/s) was significantly lower than the NONS group (94.1°/s). The 94.1°/s is comparable to the 107°/s reported in healthy female runners by Ferber et al. (2003). At this time (20% of stance) the adduction angle of both groups was approximately 9°, however, the hip abduction moment of the SYMP runners was lower than the asymptomatic runners. This trend continued such that there was a significant difference in peak hip abduction moments, occurring just prior to mid stance (SYMP: 2.25 $Nm.Kg^{-1}$ v NONS: 2.47 $Nm.Kg^{-1}$). This result is in contrast to the findings of Stefanshyn et al. (1999), who reported 20% higher knee abduction moments in PFPS runners compared with a control group.

In contrast to the findings of McClay et al. (2003) no significant between group differences were observed for peak hip internal or external rotation angles. However, on average, the SYMP runners moved into hip external rotation earlier in stance and remained in a greater degree of external rotation throughout the stance period when compared with the NONS group. The fact that both groups landed in a similar degree of internal rotation at heel strike suggests that the SYMP runners internally rotated more than the NONS during the swing phase. Overall the SYMP group displayed a larger total range of hip rotation (14.7°) when compared with the asymptomatic runners (11.7°).

Not surprisingly, the rapid movement into hip external rotation following foot contact, resulted in a significantly higher peak external rotation angular velocity of 207.8°/s for the SYMP group compared with the 172.8 °/s for the NONS group. Considering that the SYMP group attained a significantly higher hip external rotation velocity within the first half of stance it is not surprising that peak SYMP hip adduction velocity is reduced during this time period. It should also be noted that the time to peak external rotation velocity was significantly different between groups. The time to peak hip external rotation angular velocity was significantly decreased in the symptomatic subjects (24.3°/s) when compared with the non-symptomatic runners (43.6°/s). When examined in conjunction with the transverse plane motion of the knee, the result of this timing discrepancy particularly in early stance, may be of importance.

No significant differences were recorded for peak knee varus and valgus, although the SYMP group displayed on average ≈2° greater knee valgus than the NONS group between 15-100% of the stance phase. Consistent with the findings of McClay Davis et al. (2003) no difference in overall knee varus/valgus range was noted between the two groups. The only difference in the frontal plane knee results was recorded for the SYMP group, who exhibited a significantly higher varus angular velocity of 73.5°/s compared with 50.7°/s for the asymptomatic runners. A break down of the time to peak varus angular velocity shows that more of the NONS runners achieved peak varus angular velocity in the first 40% of stance compared with the SYMP runners. This clinical relevance of this finding is not immediately apparent and may simply be a function of a larger number of the NONS runners displaying a knee varus motion immediately following foot strike, before exhibiting knee valgus closer toward mid stance. A greater number of NONS runners exhibited a knee varus movement directly following heel strike when compared with a large proportion of the SYMP runners, who displayed an immediate knee valgus movement.

No previous research has reported peak varus (adduction) angular velocity in PFPS or healthy runners. However, one study has reported peak knee valgus angular velocity in asymptomatic runners. Ferber et al. (2003) reported a mean peak valgus angular velocity of 95°/s, which is comparable to the 114°/s reported for the NONS, and slightly lower than the 126°/s recorded by the SYMP runners. 83% of SYMP runners achieved peak knee valgus velocity in the first 40% of stance, which is consistent with peak hip adduction occurring between 40-50% of the stance phase. Consequently, in the first 40% of the gait cycle the NONS and SYMP groups reach peak knee (lower leg) valgus angle and peak hip adduction when the hip (thigh) is externally rotating relative to the pelvis. The transverse plane motion of the knee at this point is crucial if normal patella tracking is to be maintained.

SYMP runners made foot contact in a position of increased external knee rotation and with a similar peak internal rotation value as the NONS runners. Therefore symptomatic runners displayed a significantly increased (20.2°) range of knee internal/external rotation when compared with the asymptomatic runners (17.2°). Similarly, as the majority of both groups of runners obtained peak knee internal rotation at the same time during stance (50-60%) it is not surprising that peak internal rotation velocity of the SYMP runners was significantly higher (277.7°/s) than the NONS group 228.1°/s). The increased range of knee (lower leg) rotation relative to the hip (thigh) and the increased rate of rotation of the knee are clearly shown in Figure 1, highlighting the phase difference between the transverse plane positions of the hip and the knee (hip-knee separation angle) across the gait cycle. As previously discussed, the SYMP runners had a 10° separation angle at foot contact compared with the NONS runners of 5°. Following foot contact, both groups display hip external rotation while the knee is internally rotating. For both groups the separation angle between the two segments reached its peak at 40% of the stance phase. At this time the relative difference between the hip and knee for the SYMP runners is 20° compared with 16° for the NONS runners. The gradient of the separation angle curve in the first 40% of stance shows that the rate at which the separation angle changed occurred at a faster velocity for the SYMP compared with the NONS runners. Furthermore, the SYMP group displayed a greater range in the separation angle when compared with the NONS runners (30° v 20° respectively). The tibiofemoral joint of the SYMP runners must therefore accommodate a 10° greater discrepancy between the rotational position of the hip (thigh) and knee (lower leg) which may adversely affect patella tracking.

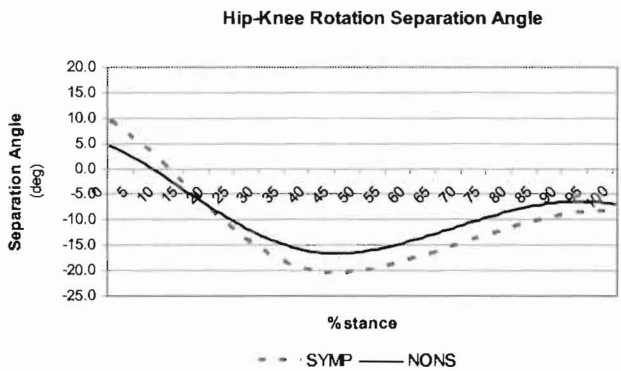

Figure 1 Symptomatic and non symptomatic hip-knee separation angles across stance.

CONCLUSION: Female runners symptomatic for PFPS displayed greater knee external rotation at foot contact when compared with non-symptomatic runners. During stance, PFPS subjects when compared with asymptomatic runners displayed; a significantly increased hip and knee internal/external rotation range, a significantly increased knee internal rotation and hip external rotation velocity. Further the average difference in hip and knee transverse plane rotations, as measured by a hip-knee separation angle was significantly greater for the PFPS subjects compared with the NONS runners. This increased separation angle infers that SYMP runners accommodated a greater degree of tibiofemoral torsion, which may be linked to increased patellofemoral maltracking and PFPS development. Further, PFPS symptomatic runners also displayed lower peak hip adduction velocity and a higher peak knee varus angular velocity during stance. Joint moment differences were observed with the symptomatic runners recording a decreased normalised hip abduction moment. The findings of this study did not reflect the common clinically held association between excessive femoral internal rotation, internal tibial rotation and knee valgus with PFPS runners. Rather, the PFPS subjects in this study displayed greater external hip and external knee rotation compared with NONS runners. Further, the greater hip external and knee internal rotation angular velocity and knee varus angular velocity of the PFPS subjects infers a different set of mechanical conditions affecting patella tracking.

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