Associations Between Anterior Knee Pain and Patellofemoral Kinematics in Cerebral Palsy

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INTRODUCTION

Flexion contractures and anterior knee pain (AKP) can severely limit function for individuals with Cerebral Palsy (CP). To date most studies evaluating AKP in patients with CP have focused on the radiographic findings of patellar fragmentation. Unfortunately, neither patellar fragmentation nor flexion contractures have been shown to be predictive of AKP in CP [1,2]. Therefore, the purpose of this study was to quantify the role that patellofemoral (PF) kinematics may play in the development of AKP in patients with CP. To accomplish this, complete 3D PF kinematics were quantified in a group of patients diagnosed with CP, but varied in their report of AKP and compared to the PF kinematics in an asymptomatic able-bodied (control) population.

METHODS

Fifteen volunteers with CP and 50 asymptomatic controls provided informed consent (or assent) prior to participating in this IRB approved study. If appropriate and time permitted, both knees were studied, creating a total study enrollment of 18 knees in the CP cohort (9M/8F, age=21.9 ± 10.8years, height = 166.4± 8.6cm, mass=57.1±10.1kg) and 60 knees in the control cohort (28M/32F, age = 26.5 ± 8.6 years, height = 170.9 ± 9.6 cm, mass = 69.0 ± 15.8kg). All participants were placed supine in an MR imager (1.5 T, GE Medical Systems, Milwaukee, WI, USA or 3.0 T, Philips Medical Systems, Best, NL) and were asked to cyclically flex and extend their knee while a dynamic cine-phase contrast (PC) MR image set (x,y,z velocity and anatomic images frames) was acquired [3]. In order to establish anatomical coordinate systems dynamic cine images (anatomic images only) were acquired in three axial planes. Integration of the velocity data enabled accurate

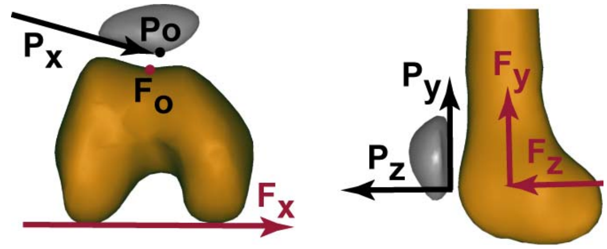

Figure 1: Schematic of the patellar and femoral coordinate systems, defined such that x,y, and z were positive in the medial, anterior, and superior directions, respectively. Flexion, medial tilt and varus rotation were in the positive x,y, and z directions, respectively.

(<0.5mm [3]) quantification of 3D PF and tibiofemoral (TF) kinematics throughout the motion cycle.

A two-way ANOVA (α=0.05) was used to compare kinematics between groups at single knee-angle increments from 40° to 10° knee extension (only 5 subjects with CP were able to extend beyond 10° and few controls could flex beyond 40° due to the closed-bore environment). For the CP cohort Spearman's ρ was used to identify associations between PF kinematics and two discrete variables: pain (yes/no) and GMFCS score (I-V). The GMFCS score indicates the level of function. A score of I indicates full independence in all mobility and a score of V indicates complete dependence for all mobility. The PF kinematics for the correlations were taken from a single knee angle (20°), which was the angle closest to full extension that all subjects with CP could reach. Discriminate analysis was used to determine if PF kinematics could predict AKP in CP.

RESULTS AND DISCUSSION

The patellae of the CP cohort were superiorly and posteriorly displaced, extended, and in varus rotation, as compared to the control population

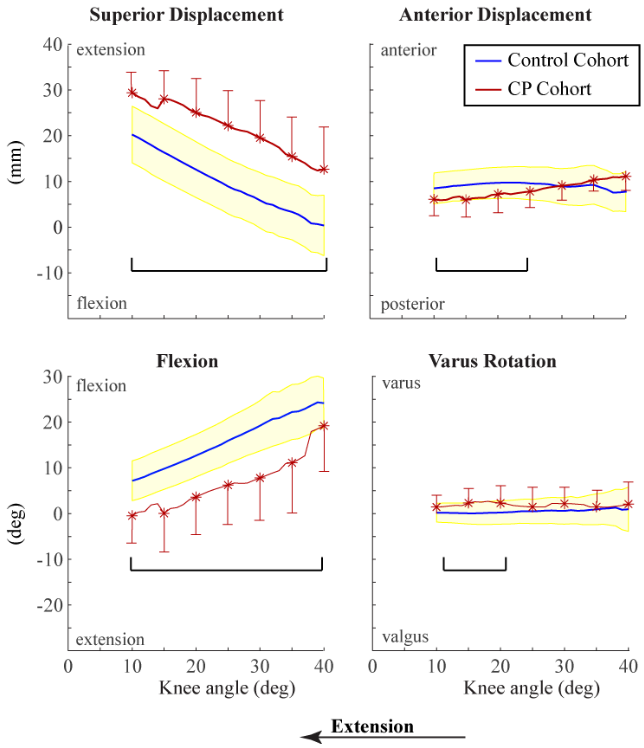

Figure 2: The four kinematic variables demonstrating significant differences between cohorts. The black lines with end caps indicate the range of knee angles where significance was found. The control population (blue) is presented with 1SD range shaded in yellow; whereas the CP cohort (red) had 1SD bars every five degrees.

(Figure 1). The CP cohort did not demonstrate significant lateral shift or tilt. In addition, the four variables demonstrating significant differences from the control population were moderately correlated to each other (superior–posterior, r = 0.70, p=0.002; superior-extension, r=0.77, p<0.001; superior-varus, r=0.67, p=-0.003). All 4 kinematic variables were significantly increased in the CP cohort with AKP (n=7), compared to the CP cohort without AKP (n=11). PF lateral displacement and tilt were not different between cohorts.

AKP and GMFCS both correlated with PF kinematics (Table 1), as well as with each other (ρ=0.57, p=0.01). Combined, PF extension and superior displacement discriminated patients with CP and AKP and those without AKP (94.4%).

This study, for the first time, identified kinematic markers that discriminated AKP in patients with CP. Interestingly, patella alta (increased PF superior displacement) has been documented in both individuals with CP and individuals without CP, but diagnosed with AKP and PF maltracking ("maltrackers"). A recent study suggested that patella alta may encourage PF dislocation in maltrackers by removing the patella from the constraints of the femoral groove (hyper-mobility) in terminal extension [4]. Yet, for the patients with CP, this was not the case. It is likely that RF tightness or spasticity, or both reduces PF lateral mobility (hypo-mobility), while pulling the patella superiorly and rotating it back onto the femoral shaft (increased extension). This promotes contact between the patellar cartilage and the femoral shaft during terminal extension. This contact may lead to excessive cartilage wear and pain. Therefore, reducing both patella alta and PF extension in patients with CP and AKP may be key to long term knee joint health.

CONCLUSIONS

Patients with higher GMFCS rating have more pronounced deformities at the knee. Specifically these individuals have increased patella alta and extension. These findings predicted the higher level of pain in this group. PF extension was also accompanied by hypo-mobility. The greater the severity of these kinematics alterations, the more likely it is for these patients with CP to experience AKP. Therefore, re-aligning the patella in patients with CP and AKP may be critical to long term knee joint health. When addressing patella alta as a cause of knee pain, it is important to consider how alterations in patellar alignment may affect other dynamic and static knee joint parameters.

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Table 1: Spearman correlation coefficients (ρ)

	Superior	Posterior	Extension	Varus
Pain	0.69(p=0.001)	0.53(p=0.02)	0.71(p<0.001)	0.49(0.03)
GMFCS	0.70(p=0.001)	-	0.69(p=0.002)	-