INTRODUCTION
Planovalgus (PV), a combination of pes planus (flat foot) and hindfoot eversion (valgus), is the most common foot deformity in ambulatory cerebral palsy (CP) patients and accounts for between 25-30% of all surgical procedures in children with CP. Despite the prevalence little research has been undertaken to quantify the extent of deviation in foot pathology compared to normal. Quantification of deviations in planovalgus feet may help understand pathologic foot function and assist in designing clinical interventions.

METHODS
Ten typically developing (TD: 7 female, 3 male, 20 feet, average age 10.6 ± 1.57 years) and eleven children with planovalgus feet (PV: 4 female, 7 male, 20 feet, average age 10.7 ± 1.80 years) were each evaluated by two clinicians. Ten subjects (TD: n=5 (10 feet), PV: n=5 (10 feet)) were reevaluated after 2-4 weeks to examine intra-clinician repeatability. Ten cameras (Vicon MX, Vicon Motion Systems) were used to record spatial positions of markers during static and dynamic (walking) trials. A 0.5x2m pedobarograph mat (FScan, RS Scan International, Belgium) was coupled with a dimensionally matched force plate (AMTI, Watertown, MA) to measure the ground reaction force. Data collection of the pressure plate system was synchronized with the force plate and marker data through an external trigger signal from the motion camera system.

Kinematic computations were performed using a model [1] written in commercially available software (BodyBuilder, Vicon, Centennial, CO). Joint angles were computed for inter-segmental joints of three foot segments (hindfoot, forefoot, toes). The kinetic computation [2] combines the marker position data collected by the camera system, ground reaction force data from the force plate and the pressure data from the pedobarograph. An inverse dynamic analysis program was written in Matlab to compute joint moments and powers over a gait cycle for three foot joints. A database of means and variability of model outcomes was established for both TD and PV groups. To test the model sensitivity, peak and range of model outcomes from the two groups were compared by using an independent samples Student t-test. To quantify the variability in both TD and PV groups, average standard deviation over a gait cycle in kinetic outcomes of the model were computed.

RESULTS
Model outcomes were found to be equally repeatable (<15%) in TD and PV groups. While comparing the kinematic outcomes between groups significant differences were observed in hindfoot valgus and flexion peaks, hindfoot flexion range of motion, forefoot motion peaks and toe flexion peak. Hindfoot flexion moment peak was smaller (10%) in PV group compared to TD. However, smaller (20%) ankle rotation moment in PV group was clinically significant. Both hindfoot and forefoot joints generated significantly smaller (37% and 31% respectively) power in the planovalgus group.

DISCUSSION
Model application yielded the first known data of (i) Multi-segment kinetics of planovalgus feet and (ii) Inter-clinician and intra-clinician variability in kinetic outcomes for both control and pathological population. The model was observed to be equally repeatable in both groups indicating its robustness in cases with foot deformity. Contrary to common expectations of larger hindfoot valgus and flexion motion in planovalgus feet [3], the PV group exhibited a smaller range of motion at the ankle joint than
the TD group. Hunt et al. [4] also observed reduced motion in PV feet but the differences observed were very small (< 2°). Differences observed using the current model are large enough (5.1°) to be considered clinically significant. Another characteristic of the planovalgus foot, excessive hindfoot valgus (6.0° difference) and smaller forefoot flexion (flat foot: 11.1° difference) were also significant in planovalgus group. The forefoot was observed to be more abducted (9.5°) in planovalgus group which is commonly expected in flat foot. Peak toe flexion was also observed to be smaller (14.8°) in planovalgus group demonstrating the absence of a medial forefoot arch. Smaller joint moment peak (10% difference) was observed at the hindfoot in the planovalgus group, which is expected due to proximal shift in center of pressure to accommodate mid-tarsal break. Joint powers were significantly smaller in planovalgus group for both hindfoot and forefoot joints. The differences in joint moment were not clinically significant (smaller than average standard deviation) but differences in inter-segmental angles were clinically significant. Therefore, it can be concluded that clinically significant differences observed in joint kinetics (power) are primarily due to change in joint motion i.e. slow and small range of motion.

REFERENCES

Figure 1: Joint angle, moments and power in sagittal plane during a gait cycle: Grey: Control group with shaded area as standard deviation. Black: Planovalgus group