Gait Analysis at Your Fingertips: Accuracy and Reliability of Mobile App Enhanced Observational Gait Analysis in Children with Cerebral Palsy

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Purpose: Three-dimensional gait analysis (3DGA) allows for quantification of gait deviation that can inform decision-making for orthopaedic surgery in children with cerebral palsy (CP). Where 3DGA is unavailable, observational gait analysis (OGA) guided by the Edinburgh Visual Gait Score (EVGS) has been shown to have acceptable reliability. The addition of mobile application slow-motion video analysis may improve the accuracy and reliability of the OGA method. This study prospectively evaluates the accuracy and reliability of mobile app enhanced OGA when compared to the gold standard of 3DGA in children with CP.

Methods: All subjects gave their informed consent for this IRB approved prospective study. Slow-motion video was captured on an iPhone 8S while simultaneous 3DGA was acquired using a 12-camera infrared system at a children's hospital Motion Analysis Center. Using the Dartfish Express app on an iPad Pro, two observers made 17 quantitative measurements per limb guided by the EVGS (Figure 1). Inter-class correlation coefficient (ICC) was used to compare reliability between observers and between methods. Pearson Correlation was used to assess the impact of transverse plane deviations on the accuracy of sagittal plane measurements.

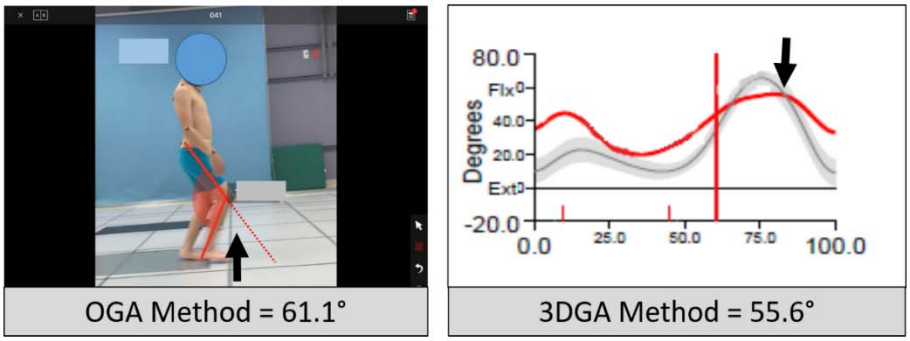


Table 1. Measurement of Peak Knee Flexion in Swing

Results: Ten subjects with CP were recruited for the study (7M, 3F; GMFCS II = 8, GMFCS III = 2; Mean 12.4y, range 7.7y to 16.4y). All subjects had significant gait deviation as measured by the Gait Profile Score (GPS), with a mean GPS of 14.10 (SD 4.18), nearly three times greater than the reference normal of 5.2 (SD 1.9). There was excellent overall reliability between raters (ICC 0.95) using mobile app enhanced OGA, and good overall reliability between OGA and 3DGA (ICC 0.89). For individual measurements, the reliability was excellent (ICC > 0.9) for 6 measures, good (ICC 0.75 – 0.9) for 5 measures, moderate (ICC 0.5 – 0.75) for 5 measures, and poor (ICC < 0.5) for 1 measure. The mean error between OGA measurement and 3DGA was 7.02° (SD 6.86°), with foot progression angle (FPA) and

knee progression angle (KPA) having among the highest mean errors (12.85° and 10.33°, respectively) (Table 1). Out of plane measurements substantially affected accuracy of the OGA method. If the FPA or KPA was greater than 20°, the accuracy of mid-stance ankle and knee position had substantially lower reliability and accuracy.

Conclusion: Mobile-enhanced OGA has good reliability between raters, allowing for enhanced communication about gait deviations in children with cerebral palsy using widely available technology. When compared to 3DGA, mobile-enhanced OGA has clinically acceptable measurement errors in the sagittal plane but should be used with caution to quantify transverse plane deviation. When rotation of the body segment exceeds 20°, sagittal plane measurements become out of plane, resulting in decreased accuracy and reliability.

The Mission of the AAP Section on Orthopedics is to foster the health of children through the AAP by mentorship, education, advocacy, and research. The AAP Section on Orthopedics has also collaborated with POSNA in joint leadership meetings creating shared strategic plans. Through these shared visions and collaborations our organizations have collectively partnered with the 50,000 pediatricians within the AAP to advocate for injured and ill children throughout the world.

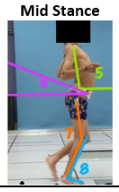
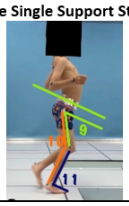
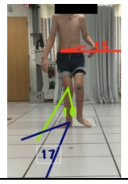
Phase of Gait	Measurement	Inter-Rater Reliability (ICC)	Reliability vs 3DGA (ICC)	Mean Error vs 3DGA [Deg (SD)]
Terminal Swing 	Pelvic Tilt (1)	0.730	0.880	2.85 (1.93)
	Knee Position (2)	0.894	0.890	4.29 (2.81)
	Ankle Position (3)	0.751	0.704	11.08 (6.96)
	Foot Inclination (4)	0.845	0.865	6.21 (4.62)
Mid Stance 	Trunk Position (5)	0.848	0.929	4.28 (4.44)
	Pelvic Tilt (6)	0.849	0.848	4.15 (2.74)
	Knee Flexion (7)	0.980	0.922	4.52 (3.29)
	Ankle Flexion (8)	0.714	0.845	8.20 (8.89)
Entire Single Support Stance 	Peak Hip Extension (9)	0.845	0.945	7.75 (3.68)
	Peak Knee Extension (10)	0.912	0.916	6.95 (4.38)
	Max Ankle Dorsiflexion (11)	0.758	0.588	9.07 (9.69)
Entire Swing 	Peak Hip Flexion (12)	0.823	0.924	7.53 (3.22)
	Peak Knee Flexion (13)	0.946	0.925	6.03 (4.14)
	Max Ankle Dorsiflexion (14)	0.840	0.635	9.75 (6.34)
Coronal 	Pelvic Obliquity (15)	0.706	0.587	3.49 (3.55)
	Knee Progression Angle (16)	0.744	0.481	10.33 (9.39)
	Foot Progression Angle (17)	0.934	0.730	12.85 (14.43)
	TOTAL	**0.951**	**0.893**	**7.02 (6.88)**

Figure 1