JURA
Journal of Undergraduate Research in Alberta • Volume 6• 2017

Examining the relationship between biomechanics and GMFCS level in children with cerebral palsy

Nicole Bowal[1,2], Gregor Kuntze[1,2], Gina Ursulak[3], Carolyn Emery[2], Janet Ronsky[1]

[1]Mechanical Engineering, University of Calgary
[2]Sports Injury Prevention Centre, University of Calgary
[3]Alberta Children's Hospital, Calgary

NICOLE BOWAL

Nicole has completed her third year in Mechanical Engineering with a Biomedical Specialization at the University of Calgary. Picking a specific research interest is difficult for Nicole as all the research areas she has been exposed to have appealed to her. However, her summer research experience in biomechanics has strengthened her resolve to pursue research in the biomedical field and she ultimately hopes to become a professor someday.

Introduction

Cerebral palsy (CP) is a non-progressive lesion of the developing central nervous system that affects the development of posture and motor control [1]. Gait analysis is used clinically to assess differences in body function in patients with CP and to inform clinical decision making [2,3]. Classification of the severity of disability is commonly performed using the Gross Motor Function Classification System (GMFCS, www.canchild.ca) or classifications of the severity of gait abnormality (e.g. Gait Deviation Index [4]). The GMFCS categorizes patients based on their functional competence using five levels ranging from least severe (I) to most severe (V) gross motor disability. Given the heterogeneity of motor outcomes in children with CP, it is important to understand differences in body function across levels of disability. Biomechanical analysis provides a quantitative approach that may allow for patient-specific functional classifications [5] to support clinical decision-making and to assess the efficacy of therapy interventions [6]. The objective of this project is to develop novel strategies for determining clinically meaningful biomechanical patient clusters. The specific aim of this study was to determine the differences in gait biomechanics (kinematics and kinetics) for children diagnosed with hemiplegic or diplegic CP categorized as either GMFCS level I or II.

Methods

Gait biomechanics of 24 children with hemiplegic or diplegic CP were analyzed as part of a secondary data analysis approved by the local ethics committee. Participants were classified according to GMFCS: Level 1 (n=12) - 12.2±1.9 yrs, 1.54±0.07 m, 46.4±12.5 kg; Level 2 (n=12) - 13.6±1.6 yrs, 1.56±0.03 m, 47.8±10.5 kg. All data were collected as part of a clinical consult over the past seven years. All biomechanical data were collected using a 12 camera motion analysis system (Motion Analysis, USA) recording at 120 Hz and 4 force plates (OR6-6, AMTI, USA) recording at 1200 Hz. Small reflective markers were affixed to the skin of the lower and upper limbs of the participants using the Helen-Hayes markerset and participants walked at their preferred pace along a raised wooden walkway.

Raw marker data were processed using Evart (Motion Analysis, USA). All kinematics and kinetics calculations were performed using Visual 3D (C-Motion, USA) to determine local coordinate systems for each lower limb segment and define mass and inertial properties of the segments using the regression equations by Dempster [7]. Joint angle and moment data were computed for five steps of the left leg across all participants. Inclusion of the right leg was not feasible across all participants due to data limitations. All data were then normalized to stance phase from heel-strike to toe-off (101 data points). Joint moments were normalized to body mass.

Statistical analyses of kinematic and kinetic waveforms were conducted in MATLAB (MathWorks, USA) using statistical parametric mapping (SPM, spm1d.org). SPM computes a t-statistic at each time point of the waveform across groups. Thereafter, Random Field Theory is used to estimate a critical threshold above which group data may be assumed to be significantly different from one another. For this analysis alpha for the critical threshold was set to 5%. The advantage of this approach was that the entire waveform could be interrogated for group differences and differences could be identified with regards to the time period during the stance phase of walking. Further, differences in gait velocity were assessed using Student's t-test in SPSS (IBM, USA).

Results

In examining the biomechanics of the hip, knee and ankle joints, two significant differences in hip joint moments were identified with respect to GMFCS levels. GMFCS level I participants displayed significantly greater hip abductor ($p=0.002$, Figure 1) and hip internal rotation ($p=0.047$,) moments between 17-26% and 18-21% of stance phase respectively. No significant differences were observed for the knee or ankle kinetics. No significant differences in joint kinematics were observed for the hip, knee or ankle joints. Further, children with GMFCS Level I walked slightly but significantly faster than those with GMFCS Level II ($p=0.009$, level 1 1.1±0.1ms^{-1}, level 2 0.9±0.2 ms^{-1}).

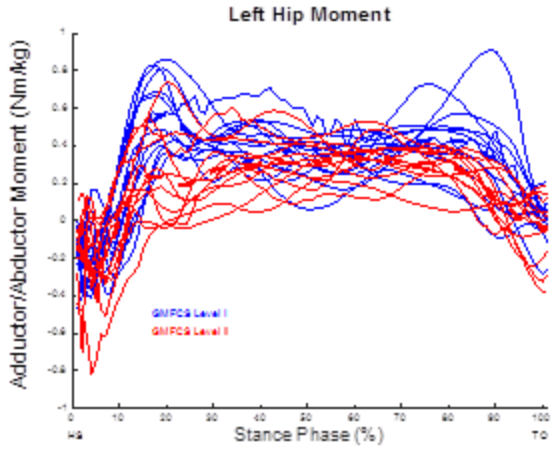

Figure 1: Left hip adductor/abductor moment. The x-axis represents the stance phase from heel strike (HS) to toe off (TO) and the y-axis is the moment in Nm/kg. The blue lines represent GMFCS Level I participants (12) and red are Level II (12). The thin lines indicate individual participants (the mean of five trials) and the thick dashed lines denote the mean of the corresponding GMFCS level.

Discussion & Conclusion

The results of this investigation demonstrated few between-group differences in gait biomechanics. The differences found at the hip abductor and internal rotation moments could be due to a number of contributing factors. They could be related to greater abductor muscle weakness in participants with lower functional competence, differences in walking speed, or due

to the effects of spasticity. Spasticity is commonly seen in children with CP and presents as increased muscle tone in response to stretch that results in resistance to movement [8]. However, the influence of spasticity on gait kinematics and kinetics for participants in this study was not determined.

Interestingly, most lower limb kinematic and kinetic measures were not significantly different with respect to GMFCS level. The primary role of the GMFCS is to predict gross motor function of children with CP with respect to their future motor function with an emphasis on sitting, walking and wheeled mobility [9]. Within this study, participants with GMFCS levels I and II displayed substantial heterogeneity with respect to the biomechanical strategies employed in the performance and control of walking. Consequent lack of distinct biomechanical patterns within GMFCS groups provide supporting evidence for a poor association between GMFCS level and subject-specific gait deviations. Confirmation of this lack of consistent biomechanical deviations within this specific population is important since all participants in this study were referred as part of a clinical consult, which could have led to unexpected results due to selection bias.

Implications

It is evident from these results that a delineation of body function in children with CP is not supported by an a priori grouping strategy using GMFCS. Indeed, a specific focus on assessing kinematic and kinetic data biomechanics using specific classification tools [e.g. 4] may be more appropriate, in line with current clinical practice [10].

Future Directions

Further research will be conducted to identify strategies for determining clusters in kinematic and kinetic data. These approaches will include unsupervised machine learning to determine optimal data clusters and supervised learning to identify appropriate criteria to classify new patients within clinically meaningful groups of body function. Sensitive and specific clustering may benefit clinical practice by providing unbiased assessment criteria and reducing the analysis burden on the clinician. Further, it may be instrumental in assessing the associations between biomechanical outcomes and clinical measures of functional capacity (e.g. spasticity and fatigue).

Acknowledgements

The NSERC Undergraduate Student Research Award provided funding support for this project. Funding is acknowledged from the Vi Riddell Pediatric Rehabilitation Research Program, (Alberta Children's Hospital Foundation) and Alberta Innovates Technology Futures.

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