GAIT PATTERNS OF CHILDREN WITH HYPOTONIA

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INTRODUCTION
Hypotonia, or decreased muscle tone, is a common diagnosis in infants and children. The presence of hypotonia is generally indicative of an underlying neuromuscular or genetic disorder, including Down syndrome. In conjunction with decreased muscle tone, children with hypotonia typically exhibit ligamentous laxity and instability of the lower limb joints, which may result in abnormal walking patterns [1]. We currently know very little about hypotonic gait patterns and treatment strategies for this disorder are controversial. The purpose of this study was to identify gait parameters that differentiated between hypotonic and normative gait patterns using statistical classifiers. A greater understanding of hypotonic walking patterns will lead to improved treatment procedures and a reduction in health care demands.

METHODS
Fifteen children, aged 3-13 years, diagnosed with hypotonia participated in the study with parental consent. Participants were recruited from the Stan Cassidy Centre for Rehabilitation in Fredericton, NB. A six-camera Vicon 512 motion capture system (Oxford Metrics Ltd.) was employed to track the three-dimensional trajectories of twenty reflective markers placed on the participants' skin at a sampling frequency of 60 Hz. Two force plates (Kistler 9281B21, AMTI BP5918) collected the three-dimensional ground reaction forces and moments during each gait cycle at a sampling frequency of 600 Hz.

A comprehensive kinematic and kinetic analysis of each child's gait was performed. The body was modeled as a series of rigid links joined by 3 degree of freedom articulations. The model consisted of the left and right foot, shank, thigh and the pelvis and trunk. Joint center locations were estimated in accordance with Davis et al. [2]. Joint angles were computed from the relative orientations of the embedded coordinate systems using Euler angles. A mathematical model (elliptical cylinder method) of the human body was used to estimate the segment inertial properties of each child [3]. Net joint moments and joint power for the hip, knee, and ankle joints were estimated using the Inverse dynamics approach.

Statistical classifiers were used to determine whether hypotonic data were significantly different from age-matched normative data. The classifier generates eight one-dimensional indices of normality for the hypotonic data [4]. The classifier examines differences in amplitude and pattern of patient gait compared to normative data. The computation of the one-dimensional indices is based on the Hotelling's T-statistic (Equation 1), which uses the normative covariance structure (Σ_B), and the difference in the means between the normative and hypotonic gait data ($B^{(i)}$).

$$D^{(i)} = \frac{82-11+1}{82\times11}\left(B^{(i)}\right)^T \sum\nolimits_{B}^{-1} B^{(i)} \qquad (1)$$

The input data for statistical tests were the eight one-dimensional indices of normality (or scores) for the hypotonic and normative groups. Four of these scores were based on kinetic gait parameters, three of these scores were based on kinematic gait parameters, and the eighth score was an overall combination of all seven scores. A series of nonparametric Mann-Whitney tests were used to test for significant differences in the median score results between the two groups of data.

RESULTS AND DISCUSSION
Significant differences were found for all scores, with the hypotonic group showing higher median (and mean) values across all scores ($p<0.05$). Therefore, as a group, hypotonic gait patterns were distinguishable from normative gait patterns based on the indices of normality. To further explore the reasons for these differences, we decomposed the indices of normality into their subcomponents and examined differences in standardized means and covariance structures between the two groups.

Differences in standardized means and covariance structures between the hypotonic and normative groups showed that hypotonic abnormalities were most readily identified by specific kinematic indices of normality. These parameters were trunk obliquity and rotation, pelvic angular acceleration, sagittal knee and ankle angles, and shank angular velocity. Kinetic parameters that contributed to the identification of hypotonic gait patterns were sagittal ankle moment, ankle power, frontal hip moment, and hip power.

Numerous differences in correlations between gait parameters were also found for the hypotonic group compared to normative data. This suggests differences in coordination and control in the hypotonic group.

CONCLUSIONS
This study identified gait parameters that could distinguish between hypotonic and normative gait patterns. A greater awareness of the gait parameters that deviate from normative values will increase our understanding of the disorder and aid in treatment planning and evaluation.

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