The Use of Principal Components Analysis to Assess Ambulatory Function Before and After Surgical Lengthening of the Hamstrings

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Introduction: Cerebral palsy is characterized by increased muscle spasticity and consequently reduced joint range of motion. Increased knee flexion during ambulation is common amongst children with cerebral palsy resulting in a crouched gait pattern.[1] Hamstring tone may be one factor contributing to crouched gait. Therefore, surgical lengthening of the hamstrings is often recommended to improve knee joint range of motion.[2] Motion analysis is a useful way to quantify the surgical outcome of hamstring lengthening, however, the complex relationships between many gait parameters make it difficult to quantitatively assess the amount of improvement. The use of principal component analyses (PCA) is one way to quantify the degree to which a child's gait deviates from typical gait in the form of an index score. This can be a useful tool to quantify improvements in overall gait performance or function at a particular joint. In the past, PCA has been used to develop a dynamic gait index and a hip function index.[3,4] In this study we applied a PCA to characterize kinematic and kinetic improvements in knee joint function as a result of a hamstring lengthening.

Statement of Clinical Significance: Establishing objective ways to characterize knee joint function enables the clinician to evaluate the magnitude of effect an intervention, such as hamstrings lengthening, has on function.

Methodology: The motion analysis data of 8 patients (mean age = 11.67 years) with cerebral palsy (4 Hemiplegic, 4 Diplegic) was assessed. All patients had a gait analysis using a six-camera motion capture system prior having a hamstrings lengthening procedure (Vicon Motion Systems, Oxford Metrics, Oxford, England) and a follow-up gait analysis after a rehabilitation period of 12-19 months (15.5 months on average). A principle component analysis on a database of 24 typically developing children, including variables descriptive of overall gait function extracted 4 principle components with an explained variance of 67%. A second principle component analysis on the same database including variables descriptive of knee joint function (knee flexion at initial contact, maximum knee extension in stance, mean knee flexion in stance, knee flexion range of motion, maximum knee extensor moment during initial stance, minimum knee flexion moment in mid-stance, maximum knee extension moment in terminal stance, maximum knee generation power in terminal stance, and minimum knee absorption power in terminal stance) extracted 3 principle components with an explained variance of 80.9%. With the scaling factors from the principle component analysis, equations were developed to determine an index descriptive of overall ambulatory function "ambulation index" and an index descriptive of knee function "knee function index". If the hamstrings lengthening procedure was unilateral, only the effected side was included in the index calculation. Student's T-tests were used to determine differences between kinematics, kinetics, and indices from pre-operative and post-operative gait analyses.

Results: A positive but, non-significant change in the ambulation index was found post-operatively (P=0.08). Significant improvements (P<0.05) were present in knee flexion angle at initial contact, knee flexion range of motion and foot progression angle. The knee function index was significantly lower post-operatively (P<0.001). In addition to knee flexion at contact and range of motion, significant improvements were present in the knee moments included in the knee function index (P<0.05).

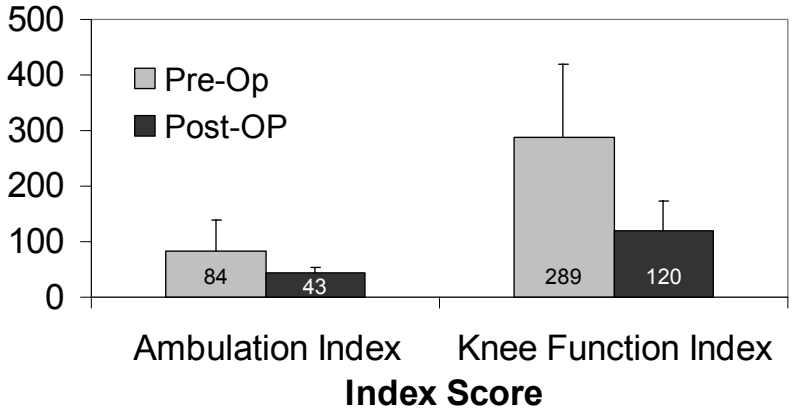

Figure 1. Group means and standard deviation bars for the "ambulation index" and "knee function index" both before and after the hamstrings lengthening procedure.

Discussion: This investigation demonstrates the use of an objective tool to characterize improvements in gait as a result of surgical hamstrings lengthening. Both the ambulation index and the knee function index were lower post-operatively, indicating improvements. The ambulation index is a useful way to quantify improvements in gait as a result of changes in kinematics at the hip knee and ankle. It was demonstrated that developing equations to determine indices specific to an intervention, such as the knee function index, can also be useful for characterizing function at a particular joint. The inclusion of kinetic variables in the knee function index may explain, in part, why it was a more sensitive measure than the ambulation index to changes in mechanics as a result of hamstrings lengthening. However, the inclusion of kinetic variables also limits this type of analysis to independent ambulators. These findings reinforce the previous work of Shutte and Novacheck in developing indices for clinical evaluation of gait.[3,4] The variables included in this analysis were investigated based on literature and experience; however, further investigation of which variables may be most indicative of function is warranted.

References:

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