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Short communication

The GDI-Kinetic: A new index for quantifying kinetic deviations from normal gait

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ABSTRACT

This article introduces a new index, the GDI-Kinetic; a direct analog of the GDI based on joint kinetics rather than kinematics. The method consists of: (1) identifying "features" of the raw gait kinetic data using singular value decomposition, (2) identifying a subset of features that account for a large percentage of the information in the raw gait kinetic data, (3) expressing the raw data from a group of typically developing children as a linear combination of these features, (4) expressing a subject's raw data as a linear combination of these features, (5) calculating the magnitude of the difference between the *subject* and the mean of the *control*, and (6) scaling and transforming the difference, in order to provide a simple, and statistically well-behaved, measure. Linear combinations of the first 20 gait features produced a 91% faithful reconstruction of the data. Concurrent and face validity for the GDI-Kinetic are presented through comparisons with the GDI, Gillette Functional Assessment Questionnaire Walking Scale (FAQ), and topographic classifications within the diagnosis of Cerebral Palsy (CP). The GDI-Kinetic and GDI are linearly related but not strongly correlated ($r^2 = 0.24$). Like the GDI, the GDI-Kinetic scales with FAQ level, distinguishes levels from one another, and is normally distributed across FAQ levels six to ten, and among typically developing children. The GDI-Kinetic also scales with respect to clinical involvement based on topographic CP classification in Hemiplegia types I–IV, Diplegia, Triplegia, and Quadriplegia. The GDI-Kinetic complements the GDI in order to give a more comprehensive measure of gait pathology.

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1. Introduction

There is a need for, and interest in, methods to quantify the amount of pathology present in the gait of patients. The needs range from gait classification to objective assessment of outcome. The interest can be seen in the number of techniques that have been proposed [1–4]. Recently, the gait deviation index (GDI) was introduced as a measure of overall gait pathology [5]. The GDI is an intuitively scaled distance between the kinematics of a pathological gait pattern and those of the average normal gait pattern; based on a reduced-order approximation of the gait cycle. The GDI has been shown to be valid, robust, and practical [6–8]. The method used to derive the GDI can be applied to a broad range of waveform signals, including gait kinetics.

The following study introduces a new index, the GDI-Kinetic; a direct analog of the GDI; based on joint kinetics rather than kinematics.

2. Methods

The methodology used to develop the GDI was applied to kinetic variables to calculate the GDI-Kinetic [5]. Briefly, the method consists of:

1. Identifying "features" of the raw gait kinetic data using singular value decomposition. This step is described in detail below.
2. Identifying a subset of features that account for a large percentage of the information in the raw gait kinetic data.
3. Expressing the raw data from a group of typically developing children as a linear combination of the features chosen in step 2 (*control feature scores*).
4. Expressing a subject's raw data as a linear combination of the features chosen in step 2 (*subject feature scores*).
5. Calculating the magnitude of the difference between the *subject feature scores* and the mean of the *control feature scores*.
6. Scaling and transforming the difference found in the step 5, in order to provide a simple, and statistically well-behaved, measure.

The data used to identify the features in steps 1 and 2 were compiled from subjects seen in our center between February 1994 and January 2010, who completed gait trials without the use of assistive devices. In each session, for each side, barefoot strides that included a clean force plate strike were averaged. This resulted in at most two strides per session for each subject, for a total of $N_{strides} = 8488$ strides from 2792 subjects (some subjects were evaluated during multiple sessions). All data had been processed using either the Vicon Clinical Manager or Plug-in-Gait model. There was no explicit filtering of the kinetics. However, cubic splines were fit to the marker trajectories which facilitates algebraic differentiation of the spatial data over time. This results in smoother kinetics than if

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